TETRA TECH EC, INC.

Memorandum

Date: February 4, 2017

To: Shanti Montgomery, HPNS Project Manager

From: Steven Adams, Tetra Tech EC., Inc. Corporate Radiation Safety Manager

Subject: Response to Comments on the Final Survey Unit Project Reports Abstract for Parcel C Sanitary Sewer and Storm Drain Removal Containing Naturally Occurring Radioactive Material (NORM) Fill Material Conducted After March 1, 2013, Dated May 6, 2015

This memorandum provides responses to the comments made by Sheetal Singh, California Department of Public Health, Environmental Management Branch on the *Final Survey Unit Project Reports Abstract for Parcel C Sanitary Sewer and Storm Drain Removal Containing Naturally Occurring Radioactive Material (NORM) Fill Material Conducted After March 1, 2013* (TtEC 2015).

Comment #1.
The reviewer can't compare sand radionuclide concentration data for Mills Peninsula, Fort Funston to the NORM Fill material. EMB suggests including several samples for Fort Funston and Building 518 sand.

Response #1
The required comparison to be made is between the radionuclide concentrations in the Building 518 sand and the radionuclide concentrations in the background reference area sand. The background reference area sand samples were obtained from an unimpacted area to the southeast of Lockwood Avenue adjacent to Parcel C. This area was selected because it has similar physical, chemical, geological, radiological, and biological characteristics as the Building 518 sand. Appendix A to Attachment 1 includes the gamma spectroscopy results for the 18 sand samples collected from the Parcel C background reference area and the gamma spectroscopy results of the 158 sand samples collected from Building 518. Statistical analysis was performed on the radium-226 (^{226}Ra) and radium-228 (^{228}Ra)/thorium-232 (^{232}Th) data of the Building 518 and the Parcel C background reference area sand samples. The 95 percent upper confidence level between the average ^{226}Ra concentration in the Building 518 sand samples and the average ^{226}Ra concentration in the Parcel C background reference area sand was 0.31 picocuries per gram (pCi/g). The 95 percent upper confidence level between the average ^{228}Ra concentration in the Building 518 sand samples and the average ^{228}Ra concentration in the Parcel C background reference area sand samples was 0.19 pCi/g. For both radionuclides, the difference between the concentrations in Building 518 sand samples and Parcel C background reference area sand samples is significantly less than the release criterion of 1 pCi/g above background.

As stated in Section 3.2.4 of the Final Survey Unit Project Report Abstract (SUPRA) a local source of import fill material was found in the Burlingame, California area from the expansion of the Mills Hospital facility. This soil was screened both chemically and radiologically before being delivered for use as residential fill material at Hunter Point Naval Shipyard (HPNS). This import fill material met the standards specified in Table A.7-1 of the Sampling and Analysis Plan (SAP) (TtEC 2008) and Worksheet #15.1 of the SAP (TtEC 2011).

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Eighteen random soil samples were collected from the Mills Hospital import fill stockpile and analyzed by gamma spectroscopy. Table 3-1 of the Final SUPRA provides a summary of the results of the import fill material from the Mills Hospital facility. The ^{226}Ra concentrations in the 18 samples ranged from a minimum of 0.327 pCi/g to a maximum of 0.545 pCi/g with a mean ^{226}Ra concentration of 0.458 pCi/g. This range of ^{226}Ra concentrations is less than that found in the two background reference soil areas at HPNS.

Excavation of the former Building 518 movie theater unearthed the foundation, which was filled with yellowish red colored sand that was clearly distinguishable from adjacent soil and sands in the area. Building 518 was indicated as non-radiologically impacted in the HPNS Historical Radiological Assessment (HRA) (NAVSEA 2004). Analytical results indicate ^{226}Ra concentrations greater than the Action Memorandum (DON 2006) release criterion of 1 pCi/g above background, in the range of 1.5 to 2.1 pCi/g. Additionally, actinium-228 (^{228}Ac) values of 1.7 to 1.9 pCi/g, indicating similar concentrations of ^{232}Th and ^{228}Ra should be present. Note that ^{228}Ac is a decay product of ^{232}Th and the parent of ^{228}Ra. The ^{228}Ra reaches secular equilibrium with ^{228}Ac in about 43 hours. In gamma spectroscopy analysis, the ^{228}Ac concentration is used to define the ^{228}Ra and ^{232}Th concentrations. Elevated cesium-137 (^{137}Cs) was nonexistent.

Isotopic uranium alpha spectroscopy of the Building 518 sand indicate secular equilibrium of uranium-238 (^{238}U) with ^{226}Ra, given the uncertainties of the analytical methods, indicating that the ^{226}Ra is naturally occurring. Given its use as a movie theatre, it does not seem likely that any radiological operations would have been conducted in Building 518. Additionally, it would seem unlikely to have large areas of ^{226}Ra contamination located with areas of ^{232}Th contamination without any other radionuclides of concern, most notably ^{137}Cs, plutonium-239 (^{239}Pu), or uranium-235 (^{235}U). Although the concentrations of the ^{226}Ra and ^{228}Ac are comparatively elevated, they are still in the range of background reference area concentrations and are therefore naturally occurring radioactive material (NORM) from the decay chains of ^{238}U and ^{232}Th, respectively. Additionally, surveys of the Building 518 structure do not indicate any areas of fixed or loose radioactive contamination.

Three samples of the sand from Building 518 were sent to Oregon State University to undergo petrographic analysis, heavy mineral separation, and X-ray diffraction (XRD) analyses to determine the composition of the material. The analyses indicated that the sand is composed primarily of quartz (both as individual grains and microcrystalline fragments, i.e., chert), volcanic fragments, iron-rich accessory minerals, and had elevated concentrations of zircon, which is known to have elevated ^{238}U and ^{232}Th concentrations. Additionally, no components such as paint chips or metals indicating sand blast operations were identified either in thin section analysis or by XRD.

The color of the sand and composition of the Building 518 sand, as determined by petrographic analysis, indicate a favorable match to the Colma Formation. The Colma Formation is a distinct yellowish to yellowish red sedimentary formation that occurs widely across South San Francisco and has been mapped in outcrop at locations across the city including Fort Funston where it is exposed along with the Merced Formation (Schlocker 1974; Bonilla 1998). Fort Funston is located in Golden Gate Park and is a radiologically non-impacted area. The Colma is highly variable in composition and has been described as a mixture of reworked Franciscan Formation (cherts, graywackes, volcanic) and granitic rocks (Yi 2005). Samples were collected from six locations at Fort Funston, starting at the top of the Colma Formation (Fort Funston 1) through the Merced Formation, finally ending at the beach which represents a mix of both Colma and Merced materials (Fort Funston 6). Gamma spectroscopy results demonstrate elevated activity concentrations of ^{226}Ra and ^{228}Ac in the samples collected from the top of the Colma Formation and from the mixed sands from the beach similar to that from the sand collected from Building 518. The Fort Funston samples were collected to provide additional evidence that the Building 518 sand is NORM. Elevated ^{226}Ra and ^{228}Ac concentrations are not uncommon throughout the San Francisco bay area.

Based on the physical composition and radionuclide concentrations in the sand in Building 518, the sand is highly likely to be locally derived and to have elevated zircon concentrations, which result in elevated concentrations of ^{238}U and ^{232}Th. This material appears similar to sand from the Colma Formation. Sand collected from Fort Funston had a similar radionuclide concentration of ^{226}Ra and ^{232}Th. It is likely that this sand was used as fill material at Building 518 after it was demolished. It is highly unlikely that the sand is due to contamination, as Building 518 was not listed as radiologically impacted in the HRA and a survey of the foundation did not indicate any levels above Atomic Energy Commission (AEC) Regulatory Guide 1.86 values (AEC 1974). Additionally, if the fill sand were from OPERATION CROSSROADS decontamination or sandblasting activities, ^{137}Cs, ^{239}Pu, and ^{235}U would have been expected in the analytical results, and elevated concentrations of ^{226}Ra and ^{232}Th would not be anticipated. The following paragraphs provide additional information and data defending the conclusion that the Building 518 sand is NORM.

The concentration of ^{226}Ra in non-impacted sand and soil typically have good fits to a Normal distribution. The concentrations of the ^{226}Ra in the Building 518 sand samples have an excellent fit to a Normal distribution with a goodness of fit of 0.994; the critical value for 158 samples is 0.9843. If the sand was contaminated, the ^{226}Ra would be skewed to higher concentrations, have a high level of kurtosis, and would not have a good fit to a Normal distribution. Attachment 1 provides details on the fit to a Normal distribution of the ^{226}Ra concentrations in the Building 518 sand samples, Parcel C background reference area soil samples, and Fort Funston sand and supports the hypothesis that the Building 518 sand is NORM.

Applying the two sample t-Test demonstrates that at the 95 percent confidence level the difference in the mean ^{226}Ra concentrations of the Building 518 and the Parcel C background reference area sand is negligible. Details of these analyses are provided in Attachment 1.

Analysis of the ^{226}Ra concentrations in the Building 518 sand demonstrates that the number of sand samples are sufficient to ensure the probability of making either a false positive or false negative decision are less than 5 percent in accordance with Multi-Agency Radiation Survey and Site Investigation Manual (NRC et. al. 2000) methodology. Details on the analysis are provided in Attachment 2.

Comment #2
The table should also include concentrations of ^{226}Ra and ^{228}Ra for each sample representative since Ra is the primary radionuclide of concern hence should be analyzed to determine the hypothesis of NORM.

Response #2
Table A.1-1 in Appendix A to Attachment 1 lists the ^{226}Ra and ^{228}Ra concentrations in the Building 518 sand samples and Table A.1-2 lists the ^{226}Ra and ^{228}Ra concentrations in the Parcel C background reference area sand samples. Table A.1-4 lists the ^{226}Ra and ^{228}Ra concentrations in the Fort Funston sand samples. The ^{228}Ra is based on the concentration of its ^{228}Ac decay product. ^{228}Ra decays directly to ^{228}Ac, which has a half-life of 6.13 hours. It only takes 43 hours for the ^{228}Ac to achieve secular equilibrium with ^{228}Ra.

Comment #3.
It is important to note that secular equilibrium suggests the radionuclides in the sand have been present for a long time and has reached secular equilibrium. This conclusion does not indicate NORM. Please further explain how the Navy has concluded the table provided is due to NORM.

Response #3

The Navy has concluded that the radionuclide concentration data demonstrates that the Building 518 sand and Fort Funston sand are NORM based on the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) definitions of NORM. The following paragraphs summarize the NRC and EPA definitions of NORM. Details on the analysis demonstrating that the Building 518 and Parcel C background reference area sand samples represent NORM are provided in Attachment 1. In addition, Attachment 3 provides details on the NRC and EPA definition of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM). TENORM is NORM that has sufficient radionuclide concentrations that it requires regulation by the NRC or EPA in order to protect the public from potential radiological risks. The regulation of TENORM as by-product material is regulated by the NRC under Title 10 Code of Federal Regulations, Part 30.4 (NRC 2007).

NORM contains radioactive concentrations in secular equilibrium with its decay chain. It requires over 156 years for all the ^{226}Ra decay products to come into secular equilibrium with the parent ^{226}Ra due to the 22.3 year half-life of lead-210. It takes over two million years for ^{226}Ra to come into secular equilibrium with ^{238}U due to the uranium-234 (half-life of 244,500 years) and thorium-230 (half-life of 77,000 years). The ^{226}Ra decay products are in secular equilibrium ensures that the ^{226}Ra is naturally occurring because radium was not used in commerce or medicine until after its discovery in 1898, only 119 years ago.

NORM is defined as materials that are radioactive, but in which the naturally occurring radioactive constituents have not been concentrated through human intervention to a level that present an unacceptable risk to workers, the public, or the environment (National Research Council 1999). The concentration of radioactive material alone are not the guiding issue for defining NORM; it is the quantitative increase in natural radioactivity resulting from human intervention that is used to define radioactive material that is regulated by the NRC, the EPA, and other Federal Agencies. Only those natural sources of ionizing radiation that pose a significant health or environmental hazard due to NORM are regulated by the NRC and EPA.

TENORM consists of discrete and diffuse sources. Attachment 3 provides the details on regulatory criteria defining the conditions under which discrete and diffuse sources of TENORM require regulatory control. The concentrations of TENORM that require regulatory control are summarized as follows.

A memorandum of understanding (MOU) between the EPA and NRC agree that concentrations of NORM in surface soil of ≤ 5 pCi/g above background for ^{226}Ra and ^{232}Th and 47 milligrams per kilogram (mg/kg) of total uranium is an acceptable cleanup criteria for unrestricted release (EPA/NRC 2002). A total uranium concentration of 47 mg/kg is equivalent to 32 pCi/g. None of the Building 518 sand samples, Parcel C background reference area sand samples, nor Fort Funston sand samples has a ^{226}Ra plus ^{232}Th concentration exceeding 5 pCi/g above background. Neither Building 518 sand, Parcel C reference background area sand, nor Fort Funston sand samples have a total uranium concentration exceeding 47 mg/kg (32 pCi/g). Details on the ^{226}Ra, ^{232}Th, and total uranium concentrations are provided in Appendix A to Attachment 1.

The Energy Policy Act of 2005 requires NRC to use model regulations, referred to as Suggested State Regulations (SSRs) that were developed by the Conference of Radiation Control Program Directors, Inc. (CRCPD) (NRC 2005). Details on the Energy Policy Act and CRCPD SSRs are provided in Attachment 3. In summary, the CRCPD SSRs states:

- Combination of ^{226}Ra and ^{228}Ra at concentrations less than 5 pCi/g, excluding natural background, are exempt from radiological controls.

- Decay progeny of the exempt NORM ^{226}Ra and ^{228}Ra are also exempt.

- Surface soil is exempt from radiological controls with up to 5 pCi/g for ^{226}Ra and ^{232}Th and 32 pCi/g for natural uranium above background averaged over an area of 100 square meters.

Analysis of Building 518 Sand

Analysis of the sand from Building 518 had elevated concentrations of zircon, which is known to have elevated ^{238}U and ^{232}Th concentrations.

Zircon is a ubiquitous trace mineral in marble, granite, slate, phyllite, and quartzite. The uranium content in zircon ranges from 10 parts per million to 1.0 percent by weight; equivalent to 3.4 pCi/g of total uranium to up to 3,000 pCi/g of total uranium (Mojzsis et. al. 2001, Ushikubo et. al. 2008, Wild et. al. 2001).

The CRCPD SSR Part N section N.4(d) *Exemptions* states: "Persons who receive, possess, use, process, transfer, or dispose of in a permitted landfill, and distribute preparation of custom blends for distribution, zirconium, zircon, and products of zirconia and zircon containing TENORM are exempt from Part N.

NORM concentrations in undisturbed background locations can vary over a very broad range of concentrations, even at locations within close proximity. Examples of the total uranium and ^{226}Ra concentrations in surface samples collected from undisturbed background locations in Arizona are listed in Table 1 (Adams and Nielson 2009, EPA 1999).

Table 1. Total Uranium and Average ^{226}Ra Concentrations in Granite Samples (pCi/g)

Location	Minimum Total Uranium Concentration	Maximum Total Uranium Concentration	Average ^{226}Ra Concentration
Bisbee, AZ, Site 1[a]	3.72	8.35	2.66
Bisbee, AZ, Site 2[a]	0.91	3.25	1.04
Bisbee, AZ, Site 3[a]	2.42	4.30	1.68
Bisbee, AZ, Site 4[a]	1.77	3.18	1.12
Bisbee, AZ, Site 5[a]	1.40	2.25	0.89
Oricale Granite near Santa Catalina Mts., AZ[b]	2.40	5.56	1.53
Dells Peak Granite near Prescott, AZ[b]	5.63	18.06	4.62
Lawler Peak Granite, Site 1 near Bagdad, AZ[b]	10.02	35.02	10.81
Lawler Peak Granite, Site 2[b]	184.7	378.5	117.8
Stockton Hills, AZ, Site 1	0.7	63.3	14.2
Stockton Hills, AZ, Site 2	0.9	60.8	16.6
Stockton Hills, AZ, Site 3	0.7	82.6	19.7

[a] Adams and Nielson 2009
[b] EPA 1999

Table 1 lists the minimum and maximum total uranium (^{234}U, ^{235}U, and ^{238}U) concentrations and average ^{226}Ra concentrations in surface granite samples collected from 12 different undisturbed background locations in Arizona. Twenty or more surface samples were collected from each sample location. The uranium and radium are due to trace quantities of zircon in the granite.

The total uranium concentrations range over two orders of magnitude from 0.9 pCi/g to 378.5 pCi/g and the average ^{226}Ra concentrations ranged from a minimum of 0.89 pCi/g to a maximum of 117.8 pCi/g. This concentration data emphasize that NORM concentrations may vary considerable even at undisturbed background locations that are in close vicinity.

Table 2 lists the range of total uranium and ^{226}Ra concentrations in surface soil samples collected from undisturbed background locations in Shoshone, California and Alamo, Nevada (McArthur and Miller 1989). The Shoshone and Alamo total uranium and ^{226}Ra concentration data is provided to demonstrate the variability and range in NORM concentrations even over very short distances between sample locations. The sample locations within each data set are within 0.5 meter of each other. Each data point represents 10 samples collected from a single sample location. Nevertheless, the average ^{226}Ra concentrations varied by 85.6 percent and the total uranium varied by 200 percent in the Shoshone surface soil samples collected from within 0.5 meter. The ^{232}Th concentrations are essentially constant for the same surface soil samples.

The total uranium and ^{226}Ra concentrations varied by 227 percent and 193 percent, respectively, in surface soil samples collected from adjacent plots in undisturbed background locations in Alamo, Nevada. The ^{232}Th concentrations in the surface soil samples collected from the same sample locations only varied by 12.9 percent (McArthur and Miller 1989).

Table 2. Total Uranium and Average ^{226}Ra Concentrations in Surface Soil Samples Collected from Undisturbed Background Locations in Shoshone, California and Alamo, Nevada (pCi/g)

Sample ID #	Minimum Total Uranium	Maximum Total Uranium	Average ^{226}Ra	Average ^{232}Th
Shoshone- BE06-1	2.25	2.47	1.18	1.19
Shoshone- BE06-2	2.45	2.91	1.34	1.18
Shoshone- BE06-3	2.84	3.32	1.54	1.15
Shoshone- BE06-4	4.24	4.52	2.19	1.12
Alamo-BE39-1	3.89	4.43	2.08	1.40
Alamo-BE39-2	3.81	4.35	2.04	1.49
Alamo-BE39-3	3.48	4.00	1.87	1.53
Alamo-BE39-4	3.41	3.91	1.83	1.58
Alamo-BE40-1	1.95	2.37	1.08	1.43
Alamo-BE40-2	2.32	2.76	1.27	1.52
Alamo-BE40-3	2.49	2.95	1.36	1.53
Alamo-BE40-4	2.47	2.93	1.35	1.51

The United States Geological Society (USGS) collected over 800 surface soil samples from remote undisturbed locations along two continental-scale transects in North America. One transect extends from northern Manitoba to the United States-Mexico border near El Paso, Texas and consists of 105 sites. The other transect approximately follows the 38th parallel from the Pacific coast of the United States near San

Francisco, California to the Atlantic coast along the Maryland shore and consists of 160 sites (Smith et. al 2005). The average total uranium concentration in all samples was 1.44 pCi/g with a standard deviation of 0.75 pCi/g. The total uranium concentrations ranged from a minimum of 0.07 pCi/g to a maximum of 25 pCi/g (Smith et. al. 2005). The ^{226}Ra concentrations ranged from a minimum of undetectable to a maximum of 11.3 pCi/g with an average of 0.7 pCi/g (Smith et. al. 2005). This USGS study provides another example of the broad range of NORM concentrations in surface soil at remote undisturbed locations.

Conclusion

The Navy asserts that based on the data analysis and regulatory definition of NORM presented above, the radionuclide concentrations in the Building 518 sand and Fort Funston sand represent NORM.

- Data analysis confirms that the ^{226}Ra, ^{228}Ra, ^{232}Th in the Building 518 sand, Parcel C reference background area sand, and Fort Funston sand samples are in secular equilibrium with their decay products. This would not be true if the sand had been contaminated with any of these three isotopes. This supports the conclusion that the soil and sand at these three locations are NORM.
- Data analysis confirms that the ^{226}Ra, ^{228}Ra, and ^{232}Th concentrations in the Building 518 sand, Parcel C reference background area sand, and Fort Funston sand samples have excellent fits to Normal distributions. This would not be true if the sand had been contaminated with any of these three isotopes. This supports the conclusion that the soil and sand at these three locations are NORM.

The sum of the ^{226}Ra and ^{232}Th concentrations and the sum of the ^{226}Ra and ^{228}Ra in the Building 518 sand, Parcel C background reference area sand, and Fort Funston sand samples are less than 5 pCi/g above background and the total uranium is less than 47 mg/kg. Therefore, the sand at these three areas comply with the definition of NORM established in the EPA/NRC MOU and CRCPD SSR Part N (EPA/NRC 2002)

In addition to the analytical data supporting the NORM classification of the Building 518 sand, Building 518 was the location of a movie theater and is indicated as non-radiologically impacted in the HPNS HRA (NAVSEA 2004). Additionally, surveys of the Building 518 structure did not indicate any areas of fixed or loose contamination. If the sand at Building 518 were from OPERATION CROSSROADS decontamination or sandblasting activities, ^{137}Cs, ^{239}Pu, and ^{235}U would have been expected in the analytical results, and elevated concentrations of ^{226}Ra and ^{232}Th would not be anticipated.

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Attachment 1

Analysis of Building 518 Sand, Parcel C Background Reference Area Sand, Mills Peninsula Sand, and Fort Funston Sand

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Analysis of Building 518 Sand, Parcel C Background Reference Area Sand, Mills Peninsula Sand, and Fort Funston Sand

Attachment 1 summarizes the results of the analysis of the radium-226 (^{226}Ra), radium-228 (^{228}Ra), and thorium-232 (^{232}Th) concentrations in sand samples collected from Building 518 and the Parcel C background reference area. The analyses were performed to demonstrate that the concentrations of these radionuclides comply with the unrestricted release criteria for naturally occurring radioactive materials (NORM) established by the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA). NORM is defined as materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, that have not been increased above background concentrations as a result of human activities (National Research Council 1999).

Background is defined as an area that has similar physical, chemical, radiological, and biological characteristics as the site area being remediated, but which has not been contaminated by human activities. The distribution and concentration of radionuclides in the background should be the same as that which would be expected on a remediation site if that site had never been contaminated. The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) states that more than one background area may be necessary for valid comparisons if a site exhibits considerable physical, chemical, radiological, or biological variability (NRC et. al. 2000).

None of the Building 518 sand samples have a ^{226}Ra plus ^{228}Ra or a ^{226}Ra plus thorium-232 (^{232}Th) concentrations exceeding the NRC and EPA unrestricted release criterion of 5 picocuries per gram (pCi/g) above background (NRC and EPA 2002, NRC 2005). Under NRC and EPA regulations, the Building 518 sand samples represent NORM. If the Building 518 sand is NORM, the ^{226}Ra and ^{228}Ra concentrations should also have a Normal distribution. There are three criteria used to determine if the radium concentrations represent a Normal distribution. The three criteria are described in the following paragraphs:

Criterion 1 – Difference between Mean and Minimum Concentrations
The difference between the mean and the minimum ^{226}Ra and ^{228}Ra concentrations should not exceed three standard deviations if the number of samples, N, is ≤ 30, or four standard deviations if N is > 30 but < 10,000 (Section 8.2.2.1 of the MARSSIM [NRC et. al. 2000]).

Criterion 2 – Difference between Mean and Median Concentrations
The difference between the mean and the median ^{226}Ra and ^{228}Ra concentrations should be significantly less than one standard deviation (Section 8.2.2.1 of the MARSSIM [NRC et. al. 2000]). The criterion used in this analysis is that the difference between the mean and median ^{226}Ra concentrations should be ≤ 0.2 standard deviations.

Criterion 3 – Fit to Normal Distribution
The distribution of the ^{226}Ra and ^{228}Ra concentrations should have a good fit to a Normal distribution. The critical values for a good fit to a Normal distribution are discussed below. There are many tests that may be applied for testing the normality of data. Some goodness-of-fit tests are superior to others in their sensitivity to different types of departures from the Normal distribution. For example, some tests are more likely to detect discrepancies between the Normal distribution and the distribution of the concentrations when the discrepancy is present in the center of the distribution, while other tests are more sensitive to a discrepancy around the tails of the distribution (Walpole and Myers 1972).

Thus, the best test cannot be selected *a priori* since it is not known where the Normal distribution and the distribution of the ^{226}Ra and ^{228}Ra concentrations are likely to differ. However, it must be emphasized that, in order for the statistical statements about a test to hold, only one test should be used for all radionuclide

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concentration data (Lurie et. al. 2011). The selection of the test should be made during the data quality objective process (Gilbert and Wilson 2000).

Finally, like every test of hypothesis, a goodness-of-fit test can at best indicate, at a pre-specified significance level, if the null hypothesis (^{226}Ra concentrations are normally distributed) should be rejected. However, if the null hypothesis is not rejected, this does not mean that the ^{226}Ra concentration data necessarily came from a Normal distribution. It usually means that it is reasonable to proceed as though the null hypothesis were true (Lurie et. al. 2011).

The most common goodness-of-fit tests for comparing data to the Normal distribution are:

- Kolmogorov-Smirnov test. This test is quite insensitive to discrepancies between an empirical distribution and the hypothesized Normal distribution in the tail areas of the empirical distribution (Lurie et. al. 2011). In this analysis, the focus is on the distribution of the higher ^{226}Ra concentration data, which is in the tail of the distribution. Therefore, the Kolmogrov-Smirnov test was rejected

- The Shapiro-Wilk test, also known as the W test. This test is limited to relatively small sample sizes and therefore, cannot be selected as there were greater than one hundred Building 518 sand samples collected and analyzed.

- Anderson-Darling test. This test should only be applied to relatively small data sets, ≤ 25 are ideal, but should not be considered for sample sizes > 300 measurements because the null hypothesis may be rejected with only slight imperfections from the Normal distribution. In addition, the critical values for the Anderson-Darling test have to be calculated for each analysis.

- Ryan-Joiner test. Ryan-Joiner test is mathematically very similar to the Shapiro-Wild Test except it is not limited to small data sets. The Ryan-Joiner test was selected to determine if the ^{226}Ra concentration data sets have a Normal distribution.

The critical values for the Ryan-Joiner test are a function of the number of concentrations in a data set and alpha (α), the probability of making a Type I decision error that the null hypothesis is rejected when it is true. Table 1 lists critical values for the Ryan-Joiner test. If the Ryan-Joiner test correlation coefficient, R, is ≥ the critical value, the null hypothesis is accepted.

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Table 1. Critical Values for the Ryan-Joiner Test (Ryan 1990)

Number of Measurements	Critical Value $\alpha = 0.010$
5	0.832
6	0.847
10	0.8804
15	0.911
18	0.914
20	0.929
25	0.9408
30	0.949
40	0.9597
50	0.9664
60	0.971
75	0.9757
80	0.9776
100	0.9818
158	0.984352
400	0.995

For the analysis of the ^{226}Ra concentration data, an α value of 0.01 is assumed. If the value of R exceeds the critical value listed in Table 1 for the number of measurements in the data set, then the null hypothesis is accepted and the distribution is assumed to be Normal.

It is important to note that, in practice, radionuclide concentrations rarely come from a distribution that fits a mathematically ideal Normal distribution. As a consequence, almost any goodness-of-fit test will result in rejection of the null hypothesis if the number of observations is very large (Lurie et. al. 2011). Thus, the outcome of such a test should be carefully interpreted. Goodness-of-fit tests provide a criterion for determining whether the agreement between the actual concentration data and a Normal distribution is close enough that the Normal distribution provides a satisfactory approximation to the actual concentration distribution. If the approximation is deemed satisfactory, then statistical methods based on the Normal distribution can be applied with some assurance that the results (inferences) are valid.

Results and Discussion

The distributions of the ^{226}Ra and ^{228}Ra concentrations in the Building 518 sand, Parcel C background reference area sand, Mills Peninsula soil, and Fort Funston Sand were evaluated against the three criteria above to defend the null hypothesis that these sand samples represent NORM. A detailed analysis of the data is provided in Appendix A. Based on an evaluation of the three criteria:

- The distribution of the ^{226}Ra and ^{228}Ra concentrations in the Building 518 samples meet all three criteria for a good fit to a Normal distribution. This is strong evidence supporting the conclusion that the sand collected from Building 518 is NORM.
- The distribution of the ^{226}Ra and ^{228}Ra concentrations in the Parcel C background reference area sand samples meet the three criteria for a good fit to a Normal distribution

The mean ^{226}Ra concentration in the Building 518 sand samples exceeds the mean ^{226}Ra concentration in the Parcel C background reference area sand samples by only 0.245 pCi/g. The mean ^{228}Ra concentration in the Building 518 sand samples exceeds the mean ^{228}Ra concentration in the Parcel C background reference area sand samples by only 0.1019 pCi/g.

In addition, an analysis was performed to determine if there is any significant differences in the ^{226}Ra and $^{228}Ra/^{232}Th$ concentrations in the Building 518 sand samples and the Parcel C background reference area sand samples. Two different tests may be used to quantify the radionuclide concentration differences, the *t*-test or the Mann-Whitney test. The *t*-test is more powerful in quantifying the difference in the radionuclide concentrations but it requires that the radionuclide concentrations in both data sets, Building 518 sand samples and the Parcel C background reference sand samples, be Normally distributed. The Mann-Whitney test is a non-parametric test that does not require the data to be Normally distributed, but it does require the data to be symmetrical.

The *t*-Test was used to determine, at the 95 percent confidence level, if there is a significant difference between the ^{226}Ra and $^{228}Ra/^{232}Th$ concentrations in the Building 518 sand samples and the Parcel C background reference area sand samples. For ^{226}Ra, the 95 percent confidence level in the lower and upper bound of the difference in the Building 518 sand samples and Parcel C background reference area sand samples are 0.1797 pCi/g and 0.3088 pCi/g, respectively. For $^{228}Ra/^{232}Th$, the 95 percent confidence level in the lower and upper bound of the difference in the Building 518 and Parcel C background reference area sand samples are 0.0170 pCi/g and 0.1869 pCi/g, respectively. Therefore, there is no significant difference between the ^{226}Ra and $^{228}Ra/^{232}Th$ concentrations in the Building 518 sand samples and the Parcel C background reference area sand samples.

Further, the NRC and EPA state that if the average concentrations of the ^{226}Ra and ^{228}Ra samples do not exceed their concentrations in the background reference area by more than 5 pCi/g then the radioactive material is NORM. The average ^{226}Ra plus ^{228}Ra concentrations in the Building 518 samples is 2.84 pCi/g and the maximum ^{226}Ra plus ^{228}Ra concentration in any of the Building 518 samples is 4.43 pCi/g in sample 04-PE-E0649-02. Therefore, the Building 518 sand is NORM.

The details of the radionuclide concentration data, Ryan-Jointer test, and *t*-Test analysis are provided in Appendix A of this attachment.

Mills Peninsula Sand

As stated in Section 3.2.4 of the Final Survey Unit Project Report Abstract, a local source of import fill material was found in the Burlingame, California area from the expansion of the Mills Hospital facility. The area where this fill material had come from had not been impacted by radiological operations. Nevertheless, this soil was screened both chemically and radiologically before being delivered for use as residential fill material at Hunters Point Naval Shipyard (HPNS). This import fill material met the standards specified in Table A.7-1 of the Sampling and Analysis Plan (SAP) (TtEC 2008) and Worksheet #15.1 of the SAP (TtEC 2011).

- The distribution of the ^{226}Ra concentrations in the Mills Peninsula sand meet the three criteria for a good fit to a Normal distribution.

Gamma spectroscopy results of the Mills Peninsula sand samples and the analysis supporting the fit to a Normal distribution are provided in Appendix A.

Fort Funston Sand Samples

Sand samples were collected from Fort Funston to illustrate the broad range of ^{226}Ra and ^{228}Ra concentrations in non-impacted areas where the Colma Formation is found in outcrops along with the Merced Formation. Fort Funston is located in the Golden Gate Park and has not been impacted by radiological operations. The relatively higher ^{226}Ra and ^{228}Ra concentrations in the Fort Funston sand are due to zircon in the granite present in both the Colma and Merced Formations. Zircon is a common component of granite and other minerals. Zircon has high concentration of natural uranium and its decay

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products. It is emphasized that the Fort Funston samples do not represent a background reference area but are geologically representative of the reddish and yellow-reddish sand found in the Building 518 foundation.

- The distribution of the ^{226}Ra concentrations in the Fort Funston sand meets two of the three criteria for a good fit to a Normal distribution.
- The distribution of the ^{228}Ra concentrations in the Fort Funston sand meets one of the three criteria for a good fit to a Normal distribution.

Details on the gamma spectroscopy results of the Fort Funston sand samples, analysis of radionuclide concentrations in the Fort Funston sand samples, and additional information on the uranium and radium concentrations in zircon are provided in Appendix A.

Conclusion

The radionuclide concentrations in the Building 518 sand samples represent NORM. The ^{226}Ra and $^{228}Ra/^{232}Th$ concentrations in the Building 518 sand samples are not significantly different from the concentrations in the Parcel C background reference area. At the 95 percent upper confidence level, the ^{226}Ra and $^{228}Ra/^{232}Th$ concentrations in the Building 518 sand samples are well below the release criterion of 1.0 pCi/g above background. The concentrations of the ^{226}Ra and $^{228}Ra/^{232}Th$ in the Building 518 and Parcel C background reference area sand samples have Normal distributions. In addition, the ^{226}Ra concentrations in the Building 518 samples are slightly lower than the ^{226}Ra concentrations in the samples collected from Fort Funston, a radiologically non-impacted location.

The Mills Peninsula soil used as import fill material at HPNS met the standards specified in Table A.7-1 of the Sampling and Analysis Plan (SAP) (TtEC 2008) and Worksheet #15.1 of the SAP (TtEC 2011). The radionuclide concentrations in the Mills Peninsula soil is less than the concentrations in samples collected from the HPNS background reference area soil.

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Appendix A

Gamma Spectroscopy Results and Analysis of Building 518 Sand, Parcel C Background Reference Area Sand, Mills Peninsula Sand, and Fort Funston Sand

Gamma Spectroscopy Results and Data Analysis of the Building 518 Sand

Table A.1-1 list the results of the gamma spectroscopy analysis of the Building 518 sand samples. The descriptive statistics of the radium-226 (^{226}Ra) and radium-228 (^{228}Ra) concentrations are listed at the end of Table A.1-1. Figures A.1-1 and A.1-2 are Normal probability plots of the ^{226}Ra and ^{228}Ra concentrations, respectively, in the Building 518 sand samples.

Table A.1-1 Gamma Spectroscopy Results of Building 518 Sand Samples (pCi/g)

Sample ID	Ra-228	Cs-137	Bi-214	Pb-214	Th-232	Ra-226	Ra-226 Plus Ra-228
04-PE-E0647-07	1.269	-0.00429	1.107	1.251	1.269	0.792	2.061
04-PE-E0647-08	1.465	0.00661	1.124	1.229	1.465	1.034	2.499
04-PE-E0647-09	1.545	0.00004	1.034	1.048	1.545	0.852	2.397
04-PE-E0647-10	1.264	0.00037	1.227	1.303	1.264	0.713	1.977
04-PE-E0647-11	1.105	0.01186	1.144	1.289	1.105	1.797	2.902
04-PE-E0647-12	1.493	-0.00013	1.090	1.216	1.493	1.094	2.587
04-PE-E0647-13	1.455	0.00916	1.090	1.120	1.455	1.218	2.673
04-PE-E0647-14	1.644	-0.00486	1.014	1.186	1.644	1.112	2.756
04-PE-E0647-15	1.512	0.00807	1.106	1.263	1.512	1.442	2.954
04-PE-E0647-16	1.677	-0.00104	1.187	1.266	1.677	1.670	3.347
04-PE-E0647-17	1.552	-0.00566	1.029	1.164	1.552	1.212	2.764
04-PE-E0647-18	1.984	0.00046	1.220	1.336	1.984	1.511	3.495
04-PE-E0647-19	1.883	-0.00701	1.232	1.318	1.883	1.676	3.559
04-PE-E0647-20	1.759	-0.00817	1.150	1.263	1.759	1.422	3.181
04-PE-E0647-21	1.559	-0.00578	1.184	1.197	1.559	0.804	2.363
04-PE-E0647-22	1.667	-0.00939	1.140	1.244	1.667	1.571	3.238
04-PE-E0647-23	1.430	-0.00007	1.030	1.235	1.430	1.710	3.140
04-PE-E0647-24	1.659	-0.00572	1.086	1.165	1.659	1.598	3.257
04-PE-E0647-25	1.500	-0.00232	1.056	1.123	1.500	1.463	2.963
04-PE-E0647-26	1.688	-0.00971	1.218	1.215	1.688	1.191	2.879
04-PE-E0648-01	1.841	-0.00759	1.263	1.414	1.841	1.431	3.272
04-PE-E0648-02	1.519	0.00273	1.058	1.304	1.519	1.242	2.761
04-PE-E0648-03	1.522	0.00000	1.232	1.277	1.522	1.433	2.955
04-PE-E0648-04	1.671	0.00000	1.170	1.223	1.671	1.609	3.280
04-PE-E0648-05	1.712	-0.00780	0.983	1.258	1.712	1.094	2.806
04-PE-E0648-06	1.638	0.00110	1.073	1.152	1.638	1.253	2.891
04-PE-E0648-07	1.885	-0.00375	1.147	1.232	1.885	1.479	3.364
04-PE-E0648-08	1.362	0.00055	1.101	1.251	1.362	1.188	2.550
04-PE-E0648-09	1.674	-0.00024	1.046	1.210	1.674	1.490	3.164
04-PE-E0648-10	1.481	-0.00059	1.149	1.140	1.481	1.771	3.252
04-PE-E0648-11	1.811	-0.00070	1.154	1.256	1.811	1.615	3.426
04-PE-E0648-12	1.788	0.01295	1.215	1.284	1.788	1.470	3.258
04-PE-E0648-13	2.105	-0.00224	1.176	1.345	2.105	1.012	3.117

Table A.1-1 (continued)

Sample ID	Ra-228	Cs-137	Bi-214	Pb-214	Th-232	Ra-226	Ra-226 Plus Ra-228
04-PE-E0648-14	1.359	0.00211	1.086	1.204	1.359	1.279	2.638
04-PE-E0648-15	1.233	-0.00429	1.016	1.214	1.233	0.962	2.195
04-PE-E0648-16	1.164	0.00189	0.956	1.030	1.164	1.655	2.819
04-PE-E0648-17	1.660	-0.01063	1.093	1.134	1.660	1.370	3.030
04-PE-E0648-18	1.591	0.00000	1.148	1.412	1.591	1.185	2.776
04-PE-E0648-19	1.451	-0.00296	1.088	1.184	1.451	0.965	2.416
04-PE-E0648-20	1.556	-0.00404	1.156	1.340	1.556	1.305	2.861
04-PE-E0648-21	1.144	-0.00803	0.677	0.857	1.144	0.830	1.974
04-PE-E0648-22	1.187	0.00010	0.866	1.030	1.187	1.156	2.343
04-PE-E0648-23	1.557	0.00365	1.128	1.188	1.557	1.718	3.275
04-PE-E0648-24	1.311	-0.00465	1.072	1.182	1.311	0.996	2.307
04-PE-E0648-25	1.578	0.00000	1.006	1.117	1.578	0.994	2.572
04-PE-E0648-26	1.323	0.00000	0.894	1.082	1.323	1.394	2.717
04-PE-E0649-01	2.391	-0.00911	1.496	1.646	2.391	1.690	4.081
04-PE-E0649-02	2.331	0.00000	1.565	1.674	2.331	2.092	4.423
04-PE-E0649-03	1.888	0.00010	1.158	1.353	1.888	1.499	3.387
04-PE-E0649-04	1.897	-0.00789	1.315	1.358	1.897	1.868	3.765
04-PE-E0649-05	1.804	0.00115	1.208	1.415	1.804	1.950	3.754
04-PE-E0649-06	2.063	-0.00248	1.330	1.477	2.063	2.073	4.136
04-PE-E0649-07	2.038	0.00000	1.304	1.503	2.038	1.092	3.130
04-PE-E0649-08	2.207	0.00086	1.458	1.546	2.207	1.645	3.852
04-PE-E0649-09	1.940	0.00461	1.319	1.360	1.940	1.228	3.168
04-PE-E0649-10	2.027	0.00008	1.179	1.346	2.027	1.650	3.677
04-PE-E0649-11	1.895	-0.00488	1.236	1.216	1.895	1.316	3.211
04-PE-E0649-12	1.701	0.00502	1.208	1.336	1.701	1.768	3.469
04-PE-E0649-13	1.798	-0.00363	1.216	1.354	1.798	1.431	3.229
04-PE-E0649-14	1.864	-0.01165	1.287	1.415	1.864	1.790	3.654
04-PE-E0649-15	1.897	-0.01330	1.261	1.283	1.897	1.711	3.608
04-PE-E0649-16	1.799	-0.00811	1.182	1.292	1.799	1.879	3.678
04-PE-E0649-17	2.119	0.00777	1.303	1.291	2.119	1.354	3.473
04-PE-E0649-18	1.388	0.00157	1.284	1.307	1.388	1.575	2.963
04-PE-E0649-19	1.998	0.00000	1.240	1.372	1.998	1.364	3.362
04-PE-E0649-20	1.975	0.00320	1.197	1.292	1.975	1.777	3.752
04-PE-E0649-21	1.906	-0.00867	1.391	1.540	1.906	1.646	3.552
04-PE-E0649-22	2.090	-0.01354	1.188	1.348	2.090	1.645	3.735
04-PE-E0649-23	1.756	0.00000	1.234	1.285	1.756	1.276	3.032
04-PE-E0649-24	1.723	-0.00259	1.241	1.286	1.723	1.023	2.746
04-PE-E0649-25	1.180	-0.00496	1.132	1.264	1.180	1.590	2.770
04-PE-E0649-26	1.851	-0.00718	1.258	1.347	1.851	1.301	3.152

Table A.1-1 (continued)

Sample ID	Ra-228	Cs-137	Bi-214	Pb-214	Th-232	Ra-226	Ra-226 Plus Ra-228
04-PE-E0650-01	1.867	-0.00786	1.040	1.215	1.867	1.590	3.457
04-PE-E0650-02	1.607	0.00578	1.084	1.106	1.607	1.349	2.956
04-PE-E0650-03	1.813	-0.00562	1.141	1.241	1.813	1.464	3.277
04-PE-E0650-04	1.682	0.00189	1.121	1.268	1.682	1.459	3.141
04-PE-E0650-05	1.087	0.00927	1.103	1.249	1.087	0.894	1.981
04-PE-E0650-06	1.456	0.00350	1.013	0.994	1.456	1.474	2.930
04-PE-E0650-07	1.359	0.00371	1.070	1.143	1.359	1.029	2.388
04-PE-E0650-08	1.922	0.00109	1.150	1.317	1.922	1.118	3.040
04-PE-E0650-09	1.375	-0.00041	0.987	1.059	1.375	1.869	3.244
04-PE-E0650-10	1.679	0.00172	1.131	1.152	1.679	1.250	2.929
04-PE-E0650-11	1.744	0.00143	1.068	1.268	1.744	1.341	3.085
04-PE-E0650-12	1.511	-0.00708	1.080	1.222	1.511	1.623	3.134
04-PE-E0650-13	1.660	0.01006	1.104	1.181	1.660	1.496	3.156
04-PE-E0650-14	1.575	0.00849	1.147	1.215	1.575	1.364	2.939
04-PE-E0650-15	1.514	0.00000	1.081	1.146	1.514	1.048	2.562
04-PE-E0650-16	1.720	0.01492	1.176	1.256	1.720	1.249	2.969
04-PE-E0650-17	1.729	-0.00298	1.132	1.258	1.729	0.949	2.678
04-PE-E0650-18	1.572	-0.00041	1.171	1.201	1.572	1.452	3.024
04-PE-E0650-19	1.780	0.00186	1.205	1.348	1.780	1.733	3.513
04-PE-E0650-20	1.932	0.00009	1.210	1.270	1.932	0.931	2.863
04-PE-E0650-21	1.819	-0.00316	1.246	1.320	1.819	1.414	3.233
04-PE-E0650-22	1.762	-0.00826	1.127	1.407	1.762	1.339	3.101
04-PE-E0650-23	1.811	0.00000	1.161	1.254	1.811	0.965	2.776
04-PE-E0650-24	1.860	-0.01401	1.290	1.391	1.860	1.591	3.451
04-PE-E0650-25	1.939	0.00000	1.258	1.358	1.939	1.674	3.613
04-PE-E0650-26	1.623	0.00266	1.102	1.289	1.623	1.635	3.258
04-PE-E0651-01	1.605	-0.01095	0.985	1.036	1.605	1.200	2.805
04-PE-E0651-02	1.615	0.00890	1.067	1.312	1.615	1.643	3.258
04-PE-E0651-03	1.626	0.00380	1.127	1.247	1.626	1.445	3.071
04-PE-E0651-04	1.728	-0.00210	1.055	1.242	1.728	1.338	3.066
04-PE-E0651-05	1.778	0.00073	1.127	1.201	1.778	1.461	3.239
04-PE-E0651-06	1.623	-0.00003	0.950	1.091	1.623	1.285	2.908
04-PE-E0651-07	1.556	0.00145	0.973	1.153	1.556	1.581	3.137
04-PE-E0651-08	1.877	-0.00945	1.130	1.286	1.877	1.769	3.646
04-PE-E0651-09	1.335	-0.00667	0.914	1.001	1.335	1.127	2.462
04-PE-E0651-10	1.543	-0.00386	1.046	1.181	1.543	1.156	2.699
04-PE-E0651-11	1.453	0.00643	1.043	1.188	1.453	1.319	2.772
04-PE-E0651-12	1.454	-0.00515	1.002	1.093	1.454	1.326	2.780
04-PE-E0651-13	1.439	0.01537	0.925	0.975	1.439	1.391	2.830

Table A.1-1 (continued)

Sample ID	Ra-228	Cs-137	Bi-214	Pb-214	Th-232	Ra-226	Ra-226 Plus Ra-228
04-PE-E0651-14	1.466	-0.00806	1.017	1.179	1.466	0.786	2.252
04-PE-E0651-15	1.191	0.00000	0.810	0.863	1.191	1.372	2.563
04-PE-E0651-16	1.490	0.00058	0.952	1.127	1.490	1.338	2.828
04-PE-E0651-17	1.442	-0.00920	0.984	0.985	1.442	1.451	2.893
04-PE-E0651-18	1.809	-0.01030	1.076	1.329	1.809	1.633	3.442
04-PE-E0651-19	1.553	0.00547	1.121	1.092	1.553	0.667	2.220
04-PE-E0651-20	1.825	-0.00149	1.126	1.280	1.825	1.168	2.993
04-PE-E0651-21	1.590	0.00421	1.012	1.139	1.590	1.211	2.801
04-PE-E0651-22	1.597	0.00923	1.028	1.155	1.597	1.673	3.270
04-PE-E0651-23	1.541	-0.01204	1.106	1.117	1.541	1.460	3.001
04-PE-E0651-24	1.715	0.01175	1.161	1.314	1.715	1.865	3.580
04-PE-E0651-25	1.749	0.01040	1.129	1.251	1.749	1.254	3.003
04-PE-E0651-26	1.612	-0.01163	1.024	1.074	1.612	1.144	2.756
04-PE-E0655-01	1.454	0.01175	0.896	1.109	1.454	0.668	2.122
04-PE-E0655-02	1.595	0.00694	1.115	1.237	1.595	1.622	3.217
04-PE-E0655-03	1.668	0.00016	1.010	1.273	1.668	1.043	2.711
04-PE-E0655-04	1.751	0.00372	1.106	1.231	1.751	1.085	2.836
04-PE-E0655-05	1.256	0.02164	0.907	0.985	1.256	1.248	2.504
04-PE-E0655-06	1.397	-0.00210	0.942	1.039	1.397	1.103	2.500
04-PE-E0655-07	1.519	0.00000	0.979	0.975	1.519	0.137	1.656
04-PE-E0655-08	1.342	-0.00806	0.870	0.973	1.342	0.842	2.184
04-PE-E0655-09	1.536	0.00616	0.944	0.983	1.536	0.936	2.472
04-PE-E0655-10	1.428	0.00274	1.075	1.171	1.428	0.954	2.382
04-PE-E0655-11	1.324	0.00013	0.926	0.996	1.324	0.822	2.146
04-PE-E0655-12	1.477	-0.00593	1.032	0.966	1.477	1.788	3.265
04-PE-E0655-13	1.572	-0.00861	1.104	1.131	1.572	1.548	3.120
04-PE-E0655-14	1.501	-0.00047	0.996	1.067	1.501	0.931	2.432
04-PE-E0655-15	1.284	-0.00389	0.940	1.021	1.284	1.311	2.595
04-PE-E0655-16	1.164	-0.00196	0.912	0.927	1.164	1.281	2.445
04-PE-E0655-17	1.235	0.01044	0.799	0.940	1.235	1.117	2.352
04-PE-E0655-18	1.114	-0.00444	0.842	0.970	1.114	0.727	1.841
04-PE-E0655-19	1.389	0.00576	0.834	0.983	1.389	1.121	2.510
04-PE-E0655-20	1.003	0.00015	0.699	0.850	1.003	0.778	1.781
04-PE-E0655-21	1.200	0.01222	0.963	0.992	1.200	0.867	2.067
04-PE-E0655-22	1.546	-0.00501	0.905	1.078	1.546	0.718	2.264
04-PE-E0655-23	1.381	-0.01389	0.842	0.953	1.381	0.948	2.329
04-PE-E0655-24	1.298	0.00078	0.864	0.957	1.298	0.900	2.198
04-PE-E0655-25	1.120	-0.00620	0.821	0.966	1.120	1.167	2.287
04-PE-E0655-26	1.469	0.00127	0.840	0.962	1.469	0.710	2.179
04-PE-E0655-27	1.332	-0.00112	0.895	0.968	1.332	1.046	2.378

Table A.1-1 (continued)

Sample ID	Ra-228	Cs-137	Bi-214	Pb-214	Th-232	Ra-226	Ra-226 Plus Ra-228
04-PE-E0655-28	0.771	0.00000	0.919	0.825	0.771	0.772	1.543
04-PE-E0655-29	1.329	0.00828	0.946	1.004	1.329	1.169	2.498
04-PE-E0655-30	1.352	-0.00844	0.846	1.000	1.352	0.713	2.065
04-PE-E0655-31	1.372	0.00206	0.989	0.884	1.372	1.127	2.499
04-PE-E0655-32	1.216	0.00000	0.993	0.901	1.216	0.692	1.908
04-PE-E0655-33	1.293	0.01553	0.899	1.008	1.293	1.119	2.412
04-PE-E0655-34	1.297	-0.00565	0.863	0.969	1.297	1.256	2.553

Descriptive Statistics: Ra-226 Concentrations in Building 518 Sand Samples (pCi/g)

```
         Total
Variable  Count   Mean    SE Mean  StDev    Variance  CoefVar  Minimum
Ra-226    158     1.3015  0.0269   0.3378   0.1141    25.95    0.1368
Variable  Q1      Median  Q3       Maximum  Skewness  Kurtosis
Ra-226    1.0758  1.3135  1.5833   2.0920   -0.22     -0.07
```

Descriptive Statistics: Ra-228 Concentrations in Building 518 Sand Samples (pCi/g)

```
          Total
Variable  Count   Mean    SE Mean  StDev    Variance  CoefVar   Minimum
Ra-228    158     1.5908  0.0215   0.2701   0.0729    16.98     0.7711
Variable  Q1      Median  Q3       Maximum  Skewness  Kurtosis
Ra-228    1.3950  1.5765  1.7820   2.3910   0.10      0.20
```

The difference between the mean and minimum ^{226}Ra concentrations is 3.45 standard deviations (1.3015-0.1368/0.3378). The difference between the mean and minimum ^{228}Ra concentrations is 3.03 standard deviations (1.5908 – 0.7711/0.2701). The distribution of the ^{226}Ra and ^{228}Ra concentrations comply with the first criterion; the difference between the mean and the minimum ^{226}Ra and ^{228}Ra concentrations does not exceed four standard deviations.

The difference between the mean and median ^{226}Ra concentrations is 0.0355 standard deviations (|1.3135 – 1.3015|/0.3378). The difference between the mean and median ^{228}Ra concentration is 0.0529 standard deviations (1.5908 – 1.5765/0.2701). The distribution of the ^{226}Ra and ^{228}Ra concentrations comply with the second criterion; the difference between the mean and the median ^{228}Ra concentrations is less than 0.2 standard deviations.

Figure A.1-1 is a normal probability plot of the ^{226}Ra concentration in sand samples collected from Building 518. The normal probability plot indicates an excellent fit to a normal distribution. The Ryan-Jointer test was used to test the ^{226}Ra concentration data for Normality. If the distribution of the ^{226}Ra concentration data was an idealized Normal distribution, the plot in Figure A.1-1 would fall on top of the straight line. In Figure A.1-1 nearly every data point is either on or very near the straight line. The value for R is 0.994 with a P value >0.1. The probability with which the null hypothesis of Normality is rejected is the level of significance and is denoted by the Greek letter α (alpha). For a data set with 158 measurements, and assuming an alpha value 0.01, the critical value for R is 0.984 (Ryan 1990). Based on the results of the Ryan-Joiner test, the ^{226}Ra concentration in the samples collected from Building 518 fits the Normal distribution with greater than a 99 percent confidence level. In addition to the R correlation, the Ryan-Joiner test results in a P-value. The P-value is the probability of getting the R correlation or lower under the assumption that the data are indeed Normal. A high P-value (>0.1) would indicate that the data do have a Normal distribution. The null hypothesis that the data is Normally distributed is accepted because R exceeds the critical value and the P-value is greater than 0.1.

Figure A.1-1 Normal Probability Plot of ^{226}Ra Concentration in Building 518 Sand Samples

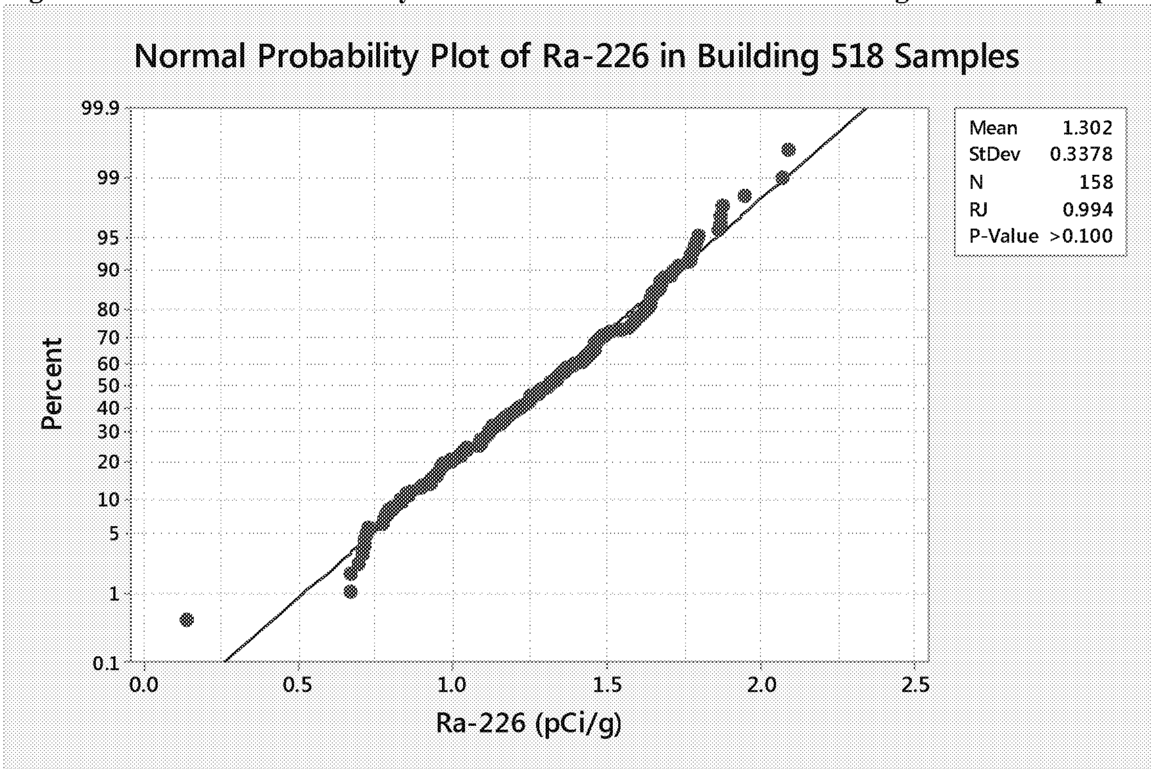
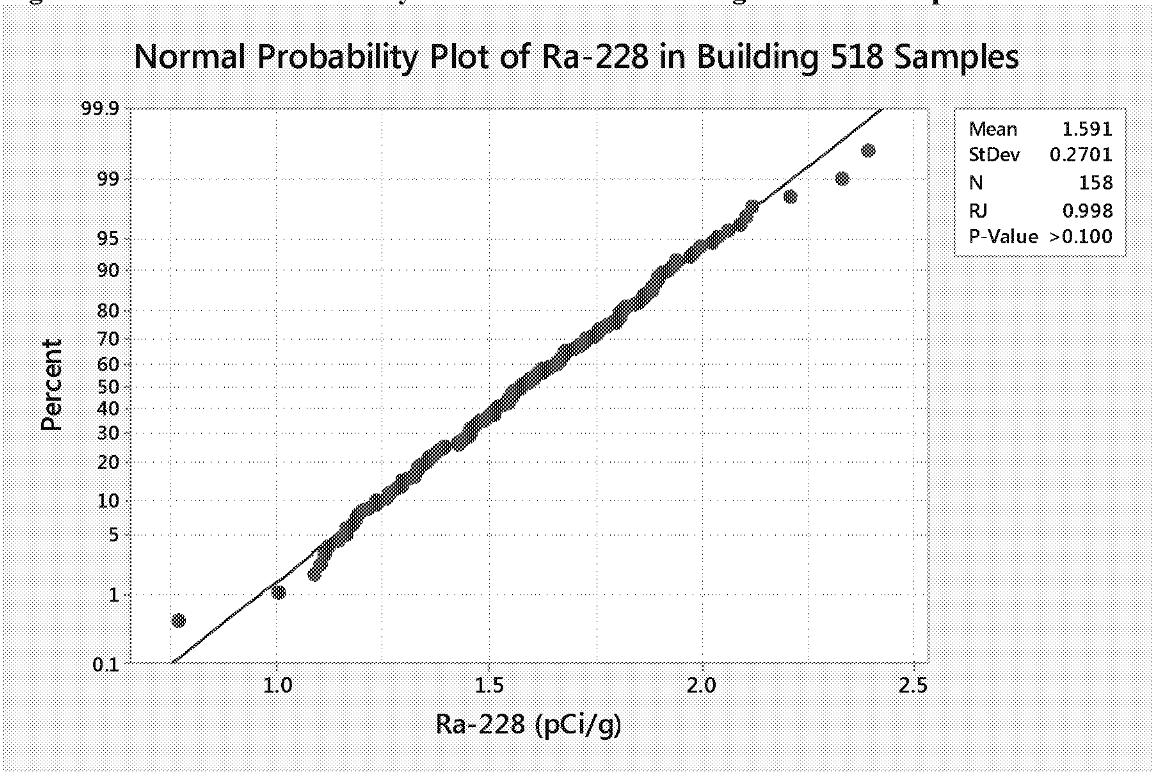


Figure A.1-2 is a normal probability plot of the ^{228}Ra concentration in samples collected from Building 518. The normal probability plot indicates an excellent fit to a normal distribution. The Ryan-Jointer test was used to test the ^{228}Ra concentration data for Normality. In Figure A.1-2, all but five data points are either on or very near the straight line. The value for R is 0.998 with a P value >0.1. Based on the results of the Ryan-Joiner test, the ^{228}Ra concentration in the samples collected from Building 518 fits the Normal distribution with greater than a 99 percent confidence level. The high P-value of >0.1 indicates that the data do have a Normal distribution. The null hypothesis that the data is Normally distributed is accepted because R exceeds the critical value and the P-value is greater than 0.1.

Figure A.1-2 Normal Probability Plot of Ra-228 in Building 518 Sand Samples



The distribution of the ^{226}Ra and ^{228}Ra concentrations in the Building 518 sand samples meet the three criteria for a Normal distribution.

Gamma Spectroscopy Results and Data Analysis of the Parcel C Background Reference Area Sand Samples

The results of the gamma spectroscopy analysis for the 18 sand samples collected from the Parcel C background reference area are listed in Table A.1-2. The descriptive statistics of the ^{226}Ra and ^{228}Ra concentrations are listed at the end of Table A.1-2. Figures A.1-3 and A.1-4 are Normal probability plots of the ^{226}Ra and ^{228}Ra concentrations, respectively, in the Parcel C background reference area.

Table A.1-2 Gamma Spectroscopy Analysis of Parcel C Background Reference Sand Samples (pCi/g)

Sample ID	Ra-228	Cs-137	Bi-214	Pb-214	Ra-226	Ra-226 plus Ra-228
12A-TURAC-001	1.538	-0.013	1.014	1.056	1.105	2.643
12A-TURAC-002	1.922	0.172	1.062	1.110	1.175	3.097
12A-TURAC-003	1.493	0.016	0.981	1.083	1.062	2.555
12A-TURAC-004	1.497	-0.018	1.032	1.141	1.060	2.557
12A-TURAC-005	1.378	-0.002	0.994	0.965	0.983	2.361
12A-TURAC-006	1.165	0.008	0.813	0.920	0.924	2.089
12A-TURAC-007	1.352	-0.004	0.907	0.943	0.945	2.297
12A-TURAC-008	1.310	-0.010	0.904	1.108	1.074	2.384
12A-TURAC-009	1.408	-0.008	0.791	0.945	0.867	2.275
12A-TURAC-010	1.744	0.006	1.054	1.153	1.091	2.835
12A-TURAC-011	1.804	0.012	1.092	1.230	1.112	2.916
12A-TURAC-012	1.349	-0.006	0.899	1.066	0.967	2.316
12A-TURAC-013	1.456	-0.006	0.903	1.101	1.053	2.509
12A-TURAC-014	1.565	0.000	1.005	1.058	0.986	2.551
12A-TURAC-015	1.445	0.010	0.778	0.944	0.966	2.411
12A-TURAC-016	1.286	0.007	1.086	1.138	1.103	2.389
12A-TURAC-017	1.619	-0.012	1.134	1.236	1.381	3.000
12A-TURAC-018	1.469	0.000	1.109	1.189	1.177	2.646

Descriptive Statistics: ^{226}Ra Concentrations in Parcel C Background Reference Sand Samples (pCi/g)

```
         Total
Variable Count  Mean    SE Mean StDev    Variance  CoefVar  Minimum
Ra-226   18     1.0573  0.0277  0.1177   0.0139    11.13    0.8670
Variable Q1     Median  Q3      Maximum  Skewness  Kurtosis
Ra-226   0.9668 1.0610  1.1067  1.3810   1.00      2.23
```

Descriptive Statistics: ^{228}Ra/^{232}Th Concentrations in Parcel C Background Reference Area Sand Samples (pCi/g)

```
         Total
Variable Count  Mean    SE Mean StDev    Variance  CoefVar   Minimum
Ra-228   18     1.4889  0.0449  0.1903   0.0362    12.78     1.1650
Variable Q1     Median  Q3      Maximum  Skewness  Kurtosis
Ra-228   1.3513 1.4625  1.5785  1.9220   0.73      0.49
```

Figure A.1-3 Normal Probability Plot of Ra-226 Concentrations in Parcel C Background Reference Area Sand Samples

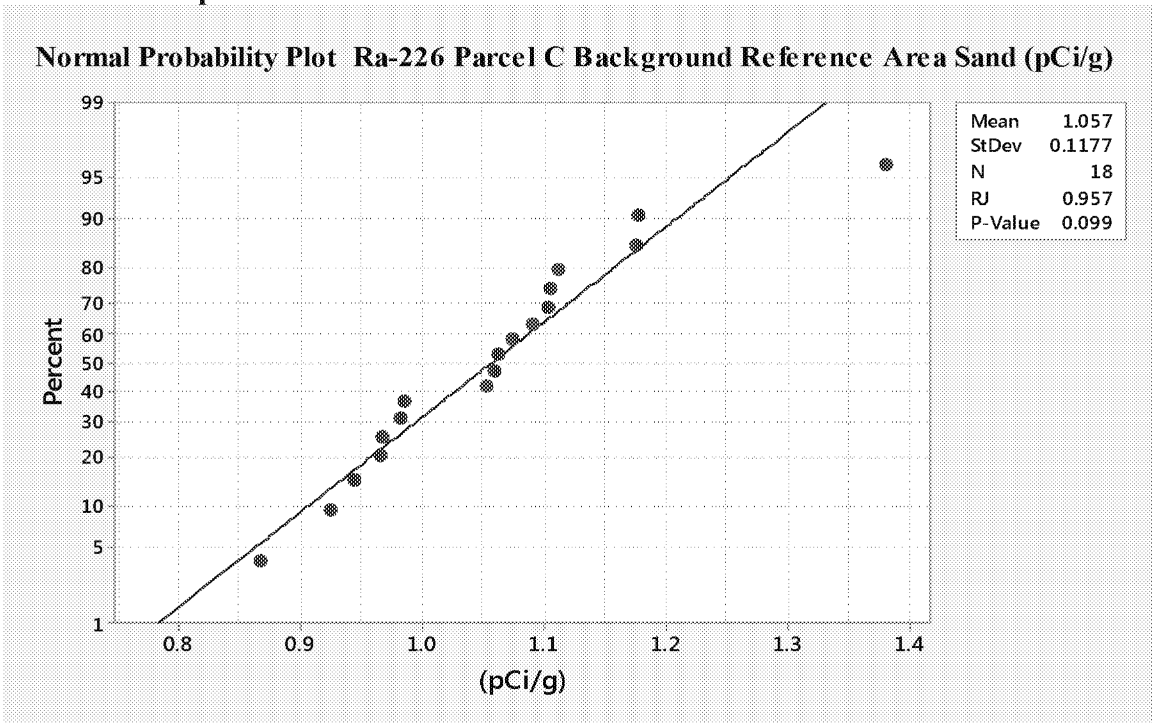
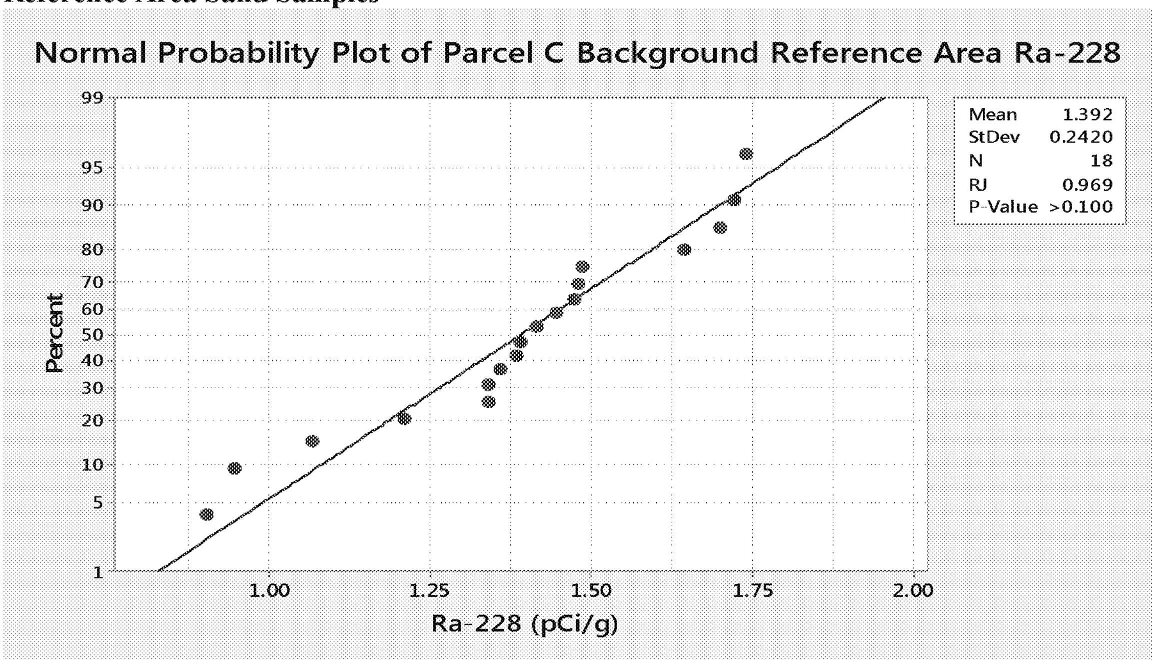


Figure A.1-4 Normal Probability Plot of Ra-228/Th-232 Concentrations in Parcel C Background Reference Area Sand Samples



The differences between the mean and minimum concentrations of ^{226}Ra and ^{228}Ra are 1.62 and 1.70 standard deviations, respectively; less than the criterion of three standard deviations for < 30 samples.

The differences between the mean and median concentrations of ^{226}Ra and ^{228}Ra are 0.0340 and 0.139 standard deviations, respectively; less than the criterion of 0.2 standard deviations.

The R values for fit to a Normal distribution for ^{226}Ra and ^{228}Ra are 0.957 and 0.969, respectively, exceeding the critical value of 0.914 for 18 samples and an α of 0.01.

The distribution of the ^{226}Ra and ^{228}Ra concentrations in the Parcel C background reference area sand samples meet the three criteria for a Normal distribution.

Descriptive Statistics: Difference Between Ra-226 Concentrations in Building 518 Sand Samples and Mean Ra-226 Concentration in Parcel C Background Reference Area Sand Samples (pCi/g)

```
          Total
Variable  Count   Mean    SE Mean  StDev     Variance  CoefVar  Minimum  Q1
Ra-226    158     0.0971  0.0269   0.3378    0.1141    347.74   -1.0676  -0.1286
Variable  Median  Q3      Maximum  Skewness  Kurtosis
Ra-226    0.1091  0.3789  0.8876   -0.22     -0.07
```

Descriptive Statistics: Difference Between Ra-228 Concentrations in Building 518 Sand Samples and Mean Ra-228 Concentration in Parcel C Background Reference Area Sand Samples(pCi/g)

```
          Total
Variable  Count   Mean    SE Mean  StDev     Variance  CoefVar Minimum  Q1
Ra-228    158     0.1019  0.0215   0.2701    0.0729    264.91  -0.7178  -0.0939
Variable  Median  Q3      Maximum  Skewness  Kurtosis
Ra-28     0.0876  0.2931  0.9021   0.10      0.20
```

Review of the ^{226}Ra and ^{228}Ra concentrations in the Building 518 sand samples demonstrates that their concentrations are not significantly greater than the concentrations in the Parcel C background reference area sand samples and far below the release criteria of 1.0 pCi/g above background. The net ^{226}Ra concentration above background in the Building 518 sand ranges from a minimum of -1.07 pCi/g to a maximum of 0.8876 pCi/g with a mean concentration of 0.097 pCi/g and a 99th percentile concentration of 0.882 pCi/g. The net ^{228}Ra concentration above background in the Building 518 sand ranges from a minimum of -0.718 pCi/g to a maximum of 0.9021 pCi/g with a mean concentration of 0.1019 pCi/g and a 99th percentile concentration of 0.730 pCi/g.

Because the ^{226}Ra and ^{228}Ra concentrations are both Normally distributed, the two-sample *t*-test was used to determine if the difference in the ^{226}Ra and the ^{228}Ra concentrations in the Building 518 and Parcel C reference background sand samples exceed 1.0 pCi/g. The two-sample *t*-Test is used to test the hypothesis that a parameter, such as the mean concentration of a set of samples, equals some specified value against an appropriate alternative, such as the mean concentration in another set of samples. The steps for testing a hypothesis concerning a population parameter, for example the mean ($\bar{x}$), against some alternative hypothesis is summarized in the following six steps.

1. H_O: $\bar{x}_1 = \bar{x}_2$
2. H_A: Alternatives are $\bar{x}_1 < \bar{x}_2$, $\bar{x}_1 > \bar{x}_2$, $\bar{x}_1 \neq \bar{x}_2$
3. Choose a level of significance equal to α, in this analysis $\alpha = 0.05$
4. Select the appropriate test statistic, in this analysis the two-sample *t*-Test
5. Compute the value of the statistic preferably from a random samples of size n_1 and n_2.
6. Accept H_O if the test result has a value in the critical region, otherwise reject H_O and accept H_A.

A review of the descriptive statistics indicate that the mean ^{226}Ra concentration in the Building 518 sand samples exceed the ^{226}Ra concentration in the Parcel C background reference area by about 0.245 pCi/g. Nevertheless, the two-sample *t*-Test was used to quantify the range of the difference between the ^{226}Ra and $^{228}Ra/^{232}Th$ concentrations in the Building 518 sand samples and the ^{226}Ra $^{226}Ra/^{232}Th$ concentrations in the Parcel C background reference area.

The critical region for the tow-sample *t*-Test = $\bar{x} - t_{0.025} \times \frac{s}{\sqrt{n}} < \mu < \bar{x} - t_{0.025} \times \frac{s}{\sqrt{n}}$

Where,

$\bar{x}$	=	Mean value of samples
$T_{0.025}$	=	α of 0.025, 95th percentile of the *t* distribution, 2-tailed test, >29 samples (1.96)
s	=	standard deviation of the samples
n	=	number of samples
μ	=	Value of the t-Test statistic

The t-Test statistic = $\dfrac{(\bar{X}_1 - \bar{X}_2) - d_0}{S_p\sqrt{(\frac{1}{n_1}) + (1/n_2)}}$

Where,

Sp	=	$\dfrac{(n_1-1)S_1^2+(n_1-1)S_2^2}{n_1+n_2-2}$ Where,
d_0	=	Difference between the two sample population means
n_1	=	Number of samples in population set #1
n_2	=	Number of samples in population set #2
S_1^2	=	Estimate of the true standard deviation squared of population set #1
S_2^2	=	Estimate of the true standard deviation squared of population set #2

The MINITAB code was used to perform the two sample *t*-Test of the difference in the ^{226}Ra and ^{228}Ra concentrations in the Building 518 and the Parcel C background reference area sand samples (MINITAB1999). The results of the *t*-Test are shown below.

Two-Sample t-Test and Confidence Interval: Does ^{226}Ra Concentration in Building 518 Sand Samples Exceed ^{226}Ra Concentration in Parcel C Background Reference Area Sand Samples

	N	Mean	StDev	SE Mean
Ra-226 Bldg. 518	158	1.302	0.338	0.027
Ra-226 Parcel C Background	18	1.057	0.118	0.028

Difference = μ (^{226}Ra Bldg. 518) - μ (Parcel C Background ^{226}Ra)
Estimate for difference: 0.2442
t-Test of difference: H_O difference is < 0.2 pCi/g, H_A difference is ≥ 0.2 pCi/g
95% lower bound for difference: 0.1797
95% upper bound for difference: 0.3088
T-Value = 1.15 P-Value = 0.872 DF = 58
P-value >0.05 so accept H_O. Difference in ^{226}Ra concentrations in the Building 518 samples and the Parcel C Background Reference Area has a lower bound of 0.1797 pCi/g and an upper bound of 0.3088 pCi/g at the 95% confidence level. Therefore, the average ^{226}Ra concentration in the Building 518 samples is less than the release criterion of 1.0 pCi/g above background.

The two-sample *t*-Test results show that the 95 percent upper confidence level is 0.3088 pCi/g in the difference between the ^{226}Ra concentration in the Building 518 sand samples and the ^{226}Ra concentration in the Parcel C background reference area. The 95 percent upper bound of 0.3088 pCi/g is less than the release criterion of 1.0 pCi/g established by the Department of the Navy in the Action Memorandum (DON 2006).

The two-sample *t*-Test was also used to quantify the range of the difference between the $^{228}Ra/^{232}Th$ concentration in the Building 518 sand samples and the ^{228}Ra concentration in the Parcel C background reference area.

Two-Sample t-Test and Confidence Interval: Does $^{228}Ra/^{232}Th$ Concentration in Building 518 Sand Samples Exceed $^{228}Ra/^{232}Th$ Concentration in Parcel C Background Reference Area Sand Samples

	N	Mean	StDev	SE Mean
$^{228}Ra/^{232}Th$ Bldg. 518	158	1.591	0.270	0.021
Ra-228 Parcel C Background	18	1.489	0.190	0.045

Estimate of the difference: 0.1020
T-Value = -1.97 P-Value = 0.970 DF = 25
Estimate for difference: H_O difference is < 0.1020 pCi/g, H_A difference is ≥ 0.1020 pCi/g
95% lower bound for difference: 0.017 and 95% upper bound is 0.1869 pCi/g.
T-Value = -0.11, P-Value = 0.500, DF = 25

P-value is >0.05 so accept H_O. Difference in $^{228}Ra/^{232}Th$ concentrations in the Building 518 samples and the Parcel C Background Reference Area has a lower bound of 0.0170 pCi/g and an upper bound of 0.1869 pCi/g at the 95% confidence level. Therefore, the average ^{228}Ra concentration in the Building 518 samples is less than the release criterion of 1.0 pCi/g above background.

The *t*-Test results demonstrate that the difference between the ^{226}Ra and ^{228}Ra concentrations in the Building 518 and Parcel C background reference area sand is less than the release criteria of 1.0 pCi/g. More specifically, at the 95 percent upper confidence level the difference between the ^{228}Ra concentration in the Building 518 sand samples and the ^{228}Ra concentration in the Parcel C background reference area is only 0.1869 pCi/g. The 95 percent upper confidence level is less than the release criterion of 1.0 pCi/g established by the Department of the Navy in the Action Memorandum (DON 2006).

Conclusion

The two-sample *t*-Test of the the^{226}Ra and ^{228}Ra concentrations in the Building 518 and Parcel C background reference area sand samples proves that the 95 percent lower and upper confidence level of the difference in their mean concentrations being within 0.1797 to 0.3088 pCi/g and 0.017 to 0.1869 pCi/g, respectively. The mean ^{226}Ra and ^{228}Ra concentrations in the Building 518 sand meets the release criterion of ≤ 1.0 pCi/g above background and the Building 518 sand consist of NORM.

Gamma Spectroscopy and Data Analysis of Mills Peninsula Soil Samples

Table A.1-3 lists the ^{137}Cs and ^{226}Ra concentrations in the 18 Mills Peninsula soil samples. The descriptive statistics for the ^{226}Ra concentrations are listed below Table A.1-3. Figure A.1-5 is the Normal probability plot of the ^{226}Ra concentrations in the Mills Peninsula soil samples.

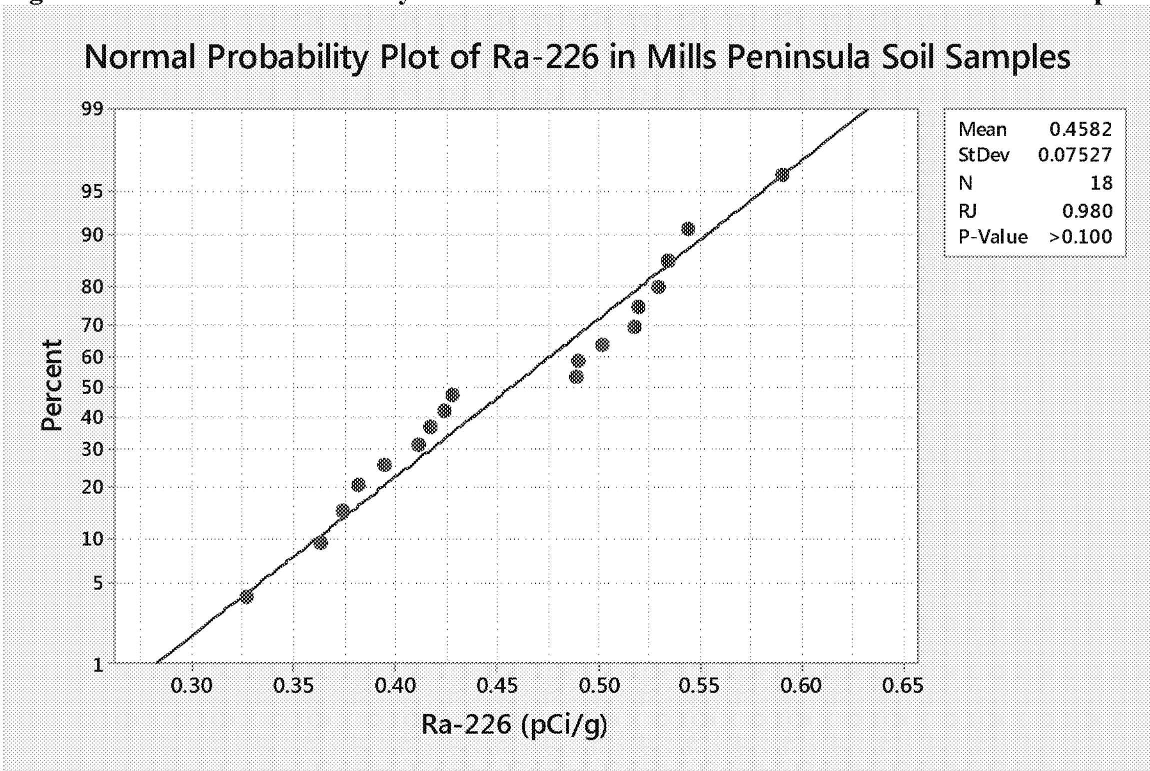
Table A.1-3 Cs-137 and Ra-226 Concentrations in Mills Peninsula Soil Samples (pCi/g)

Sample ID	Cs-137	Ra-226
1	0.027	0.545
2	0.007	0.491
3	0.015	0.591
4	0.007	0.530
5	0.000	0.395
6	0.027	0.535
7	-0.007	0.490
8	0.011	0.382
9	0.000	0.364
10	0.006	0.327
11	-0.009	0.412
12	0.002	0.425
13	0.002	0.374
14	0.005	0.429
15	-0.006	0.418
16	-0.009	0.520
17	0.020	0.502
18	-0.002	0.518

Descriptive Statistics: Ra-226 Concentrations in Soil Samples Collected from Mills Peninsula (pCi/g)

```
          Total
Variable  Count    Mean    SE Mean  StDev    Variance  CoefVar   Minimum
Ra-226    18       0.4582  0.0177   0.0753   0.0057    16.43     0.3270
Variable  Q1       Median  Q3       Maximum  Skewness  Kurtosis
Ra-226    0.3918   0.4595  0.5225   0.5910   -0.03     -1.14
```

Figure A.1-5 Normal Probability Plot of Ra-226 Concentrations in Mills Peninsula Samples



The differences between the mean and minimum ^{226}Ra concentrations is 1.74 standard deviations; less than the criterion of three standard deviations for <30 samples.

The differences between the mean and median ^{226}Ra concentrations is 0.0173 standard deviations; less than the criterion of 0.2 standard deviations.

The R values for ^{226}Ra is 0.980, exceeding the critical value of 0.914 for 18 samples and an α of 0.01 with a P-Value of > 0.100.

The distribution of the ^{226}Ra concentrations in the Mills Peninsula fill material meet the three criteria for a Normal distribution.

The ^{226}Ra concentrations are also low in comparison to the background reference areas at HPNS. The average ^{226}Ra concentration is 0.4582 pCi/g and the maximum ^{226}Ra concentration is 0.591 pCi/g, less than the 0.7 pCi/g found in background reference areas throughout HPNS. The ^{137}Cs concentrations are essentially nonexistent, the mean concentration is 0.00533 pCi/g.

Gamma Spectroscopy Results and Data Analysis of the Fort Funston Sand

Table A.1-4 lists the ^{226}Ra and ^{228}Ra concentrations in the six Fort Funston sand samples. The descriptive statistics for the ^{226}Ra concentrations are listed below Table A1-4. Figures A.1-6 and A.1-7 are the Normal probability plot of the ^{226}Ra and ^{228}Ra concentrations, respectively, in the Fort Funston sand samples.

Table A.1-4 Gamma Spectroscopy Results for the Fort Funston Sand Samples (pCi/g)

Sample ID	Bi-214	Pb-214	Ra-226	Ra-228	Ra-226 plus Ra-228
04A-FUNST-001	1.165	1.319	1.903	1.642	3.545
04A-FUNST-002	0.4455	0.5622	0.5622[a]	1.071	1.633
04A-FUNST-003	1.084	1.129	1.334	1.476	2.810
04A-FUNST-004	0.8673	1.085	1.384	1.382	2.766
04A-FUNST-005	0.9753	1.14	0.8795	1.505	2.385
04A-FUNST-006	2.534	2.673	3.565	3.891	7.456

Notes:

a. Interference from 186 keV gammas emitted from ^{235}U resulted in poor quality ^{226}Ra spectra, ^{214}Pb, decay product of ^{226}Ra, concentration used in lieu of ^{226}Ra.

^{228}Ra and ^{232}Th concentration is based on the concentration of their decay product ^{228}Ac
Sum of the ^{226}Ra and ^{232}Th concentrations is the same as the sum of the ^{226}Ra and ^{228}Ra.

Descriptive Statistics: Ra-226 Concentrations in Fort Funston Sand Samples (pCi/g)

```
         Total
Variable  Count  Mean     SE Mean   StDev     Variance  CoefVar  Q1     Median
Ra-226    6      1.605    0.435     1.065     1.133     66.34    0.800  1.359
Variable  Q3     Maximum  Skewness  Kurtosis  CoefVar   Minimum
Ra-226    2.318  3.565    1.50      2.60      66.34     0.562
```

Descriptive Statistics: Ra-228 Concentrations in Fort Funston Sand Samples (pCi/g)

```
         Total
Variable  Count  Mean     SE Mean  StDev    Variance  CoefVar  Minimum
Ra-228    14     1.828    0.420    1.029    1.058     56.28    1.071
Variable  Q1     Median   Q3       Maximum  Skewness  Kurtosis
Ra-228    1.304  1.490    2.204    3.891    2.25      5.32
```

Figure A.1-6 is a normal probability plot of the ^{226}Ra concentrations in sand samples collected from Fort Funston. The normal probability plot of the ^{226}Ra concentration in sand samples collected from Fort Funston indicates an excellent fit to a Normal distribution. The Ryan-Jointer test was used to test the ^{226}Ra concentration data for Normality. For a data set with six measurements and assuming an alpha value 0.01, the critical value for R is 0.847 (Ryan 1990). Based on the results of the Ryan-Joiner test, the ^{226}Ra concentration in the sand samples collected from Fort Funston fits the Normal distribution with greater than a 99 percent confidence level. The high P-value (>0.1) indicates that the ^{226}Ra concentrations do have a Normal distribution. The null hypothesis that the data is Normally distributed is accepted because R exceeds the critical value and the P-value is greater than 0.1.

Figure A.1-6 Normal Probability Plot of ^{226}Ra Concentration in Fort Funston Sand

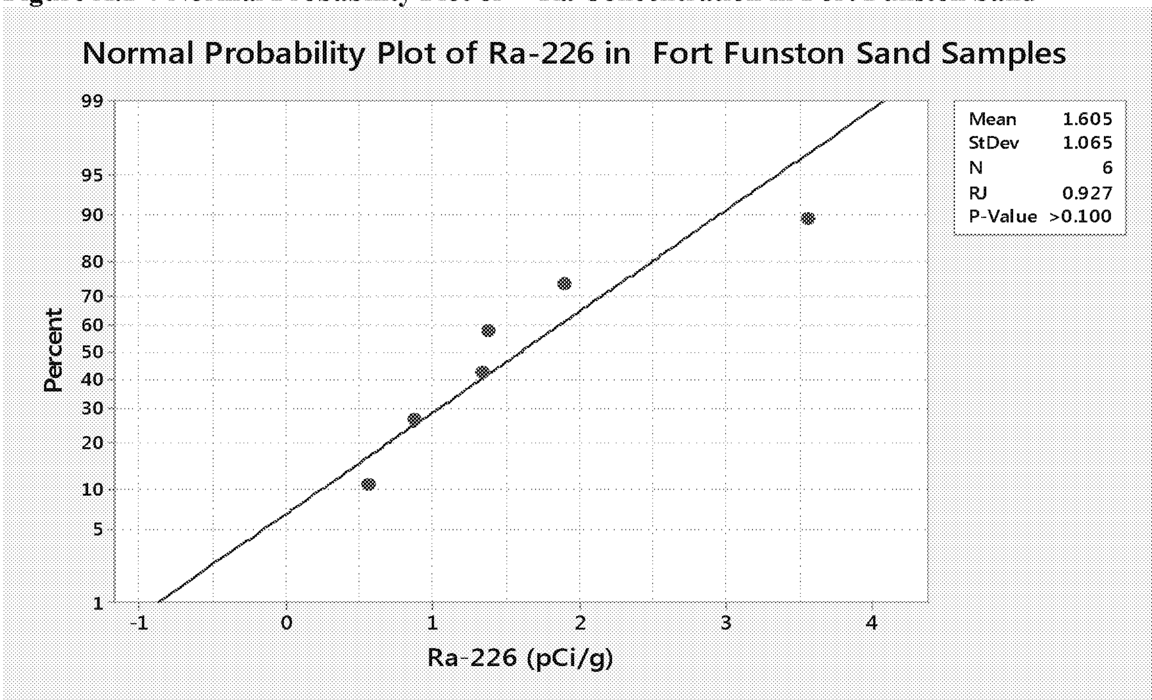
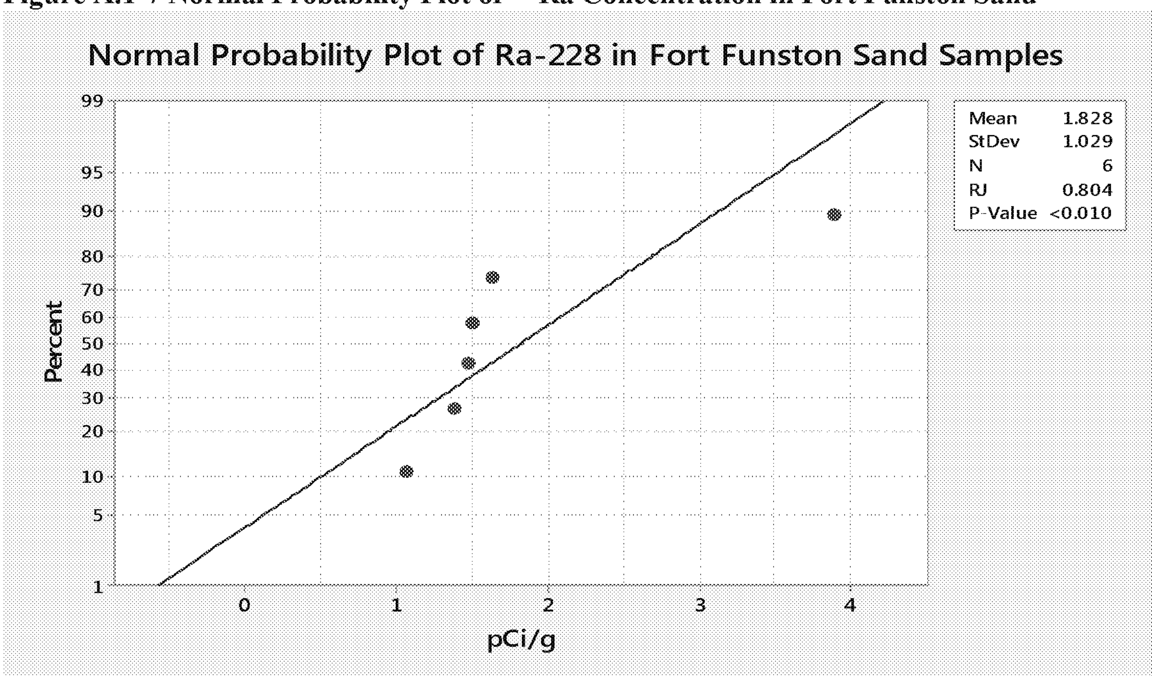


Figure A.1-7 Normal Probability Plot of ^{228}Ra Concentration in Fort Funston Sand



The differences between the mean and minimum ^{226}Ra and ^{228}Ra concentrations is 0.979 and 0.736 standard deviations, respectively; less than the criterion of three standard deviations for <30 samples.

The differences between the mean and median ^{226}Ra and ^{228}Ra concentrations is 0.231 and 0.328 standard deviations, respectively; this exceeds the criterion of 0.2 standard deviations.

The R values for ^{226}Ra is 0.927, exceeding the critical value of 0.847 for six samples and an α of 0.01 with a P-Value of > 0.100.

The R values for ^{228}Ra is 0.804, less than the critical value of 0.847 for six samples and an α 0.01 with a P-Value of < 0.010.

The distribution of the ^{226}Ra and ^{228}Ra concentrations in the Fort Funston sand does not meet all three criteria for a Normal distribution. However, the Fort Funston sand is still NORM because the concentrations are not different from concentrations reported in samples collected from the same geological formations, the Colman and Merced Formations. The Colma Formation is a distinct yellowish to yellowish red sedimentary formation that occurs widely across South San Francisco and has been mapped in outcrop at locations across the city including Fort Funston where it is exposed along with the Merced Formation (Schlocker 1974, Bonilla 1998). Fort Funston is located in the Golden Gate Park and is a radiologically non-impacted area. The Colma Formation is highly variable in composition and has been described as a mixture of reworked Franciscan Formation (cherts, graywackes, volcanic) and granitic rocks (Yi 2005). Samples were collected from six locations at Fort Funston, starting at the top of the Colma Formation (Fort Funston 1) through the Merced Formation, finally ending at the beach which represents a mix of both Colma and Merced materials (Fort Funston 6). The ^{226}Ra and ^{228}Ra concentrations in the Fort Funston sand samples are not elevated in comparison to the concentrations in the Colma Formation and Merced Formation reported at other locations. The granite in the Colman and Merced Formations have relatively high concentrations of zircon. Zircon is a ubiquitous trace mineral in marble, granite, slate, phyllite, and quartzite. The uranium content in zircon ranges from 10 parts per million to 1.0 percent by weight; equivalent to 3.4 pCi/g of total uranium to up to 3,000 pCi/g of total uranium (Mojzsis et. al. 2001, Ushikubo et. al. 2008, Wild et. al. 2001).

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Attachment 2

Analysis of the Number of Samples Collected of the Building 518 Sand and Fort Funston Sand

Purpose

Calculate the number of samples to characterize radionuclide concentrations in Building 518 sand.

Introduction

This analysis addresses the number of samples required to fully characterize the radium-226 (^{226}Ra) and radium-228 (^{228}Ra) concentrations to support a conclusion the sand is naturally occurring radioactive material (NORM). The number of samples to be collected is a function of the derived concentration guideline level (DCGL), lower bound of the gray region (LBGR), standard deviation in the ^{226}Ra and ^{228}Ra concentrations, relative shift in their concentrations, and the acceptable false positive and false negative decision uncertainty. Each of these parameters are addressed in the following section.

Given

The required number of samples to be collected from Building 518 sand, N/2, is calculated using Equation (1), which is the same as Equation 5-1 in MARSSIM (NRC et. al. 2000).

Mean ^{226}Ra concentration in Parcel C NORM background reference area (pCi/g) = 1.0573

Mean ^{228}Ra concentration in Parcel C NORM background reference area (pCi/g) = 1.4889

DCGL = 1 pCi/g above the mean ^{226}Ra concentration in the Parcel C background reference area

DCGL is not defined for ^{228}Ra, assume 1 pCi/g above Parcel C background reference area

^{226}Ra DCGL (pCi/g) = 2.0573

^{228}Ra DCGL (pCi/g) = 2.4889

LBGR = one-half of the ^{226}Ra DCGL = 2.0573/2 = 1.029 pCi/g)

LBGR = one-half of the ^{228}Ra DCGL = 2.4889/2 = 1.24445 pCi/g)

Δ = shift = DCGL - LBGR (pCi/g) = 1.029 pCi/g for ^{226}Ra and 1.24445 pCi/g for ^{228}Ra

σ_{Ra226} = standard deviation of the ^{226}Ra concentration (pCi/g) = 0.1177 (from Attachment 1)

σ_{Ra228} = standard deviation of the ^{228}Ra concentration (pCi/g) = 0.1903

Δ/σ_{Ra226} = relative shift (pCi/g) = 1.029/0.1177 = 8.739592

Δ/σ_{Ra228} = relative shift (pCi/g) = 1.24445/0.1903 = 6.539411

α (alpha) = specified maximum probability of a false positive (Type I) decision error = 0.05

β (beta) = specified maximum probability of a false negative (Type II) decision error = 0.05

$Z_{1-\alpha}$ = percentile of the alpha decision error rate = 1.645 (Table 5.2 MARSSIM)

$Z_{1-\beta}$ = percentile of the beta decision error rate = 1.645 (Table 5.2 MARSSIM)

Calculations

$$N = (Z_{1-\alpha} + Z_{1-\beta})^2 / 3(P_r - 0.5)^2 \times 1.2 \qquad \text{Eq. (1)}$$

Where,

P_r = function of Δ/σ from Table 5.1 of MARSSIM, for $\Delta/\sigma > 3.0$ Pr = 0.983039

1.2 = ensure sufficient power due to uncertainty in calculated parameter values

$N = (1.645 + 1.645)^2/3(0.983039 - 0.5)^2 \times 1.2 =$ 18.55613

N is the total number of samples to be collected from the survey unit and the background reference area. MARSSIM recommends that one-half of the samples be collected from the survey unit. One-half of N is 9.278 then rounding up to the next highest integer is ten.

The relative shift of the ^{228}Ra concentrations in the Building 518 sand is less than the ^{226}Ra but still >3.0. Therefore, the number of samples required to ensure a 5% upper limit on the Type 1 and Type II decision errors is the same ten sand samples required for ^{226}Ra.

Conclusion

Ten sand samples were needed to be collected from Building 518 but 18 sand samples were collected. Therefore, the number of sand samples collected from Building 518 were more than sufficient.

Reference

Nuclear Regulatory Commission (NRC). 2000. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). NUREG -1575, Rev. 1, EPA 402-R-97-016, Rev. 1, DOE/EH-0624, Rev. 1, Washington DC

PURPOSE

Determine if the number of sand samples collected from Fort Funston ensure sufficient confidence in the calculated mean and standard deviation in the ^{226}Ra concentration.

INTRODUCTION

R. O. Gilbert developed a method for calculating the number of samples required to ensure the difference between the true mean and sample mean concentrations of an environmental pollutant is less than a specified value. It is applied here to calculate if the number of samples collected from the Fort Funston sand ensure the difference between the mean ^{226}Ra concentration in the sand samples and the the true mean ^{226}Ra concentration in the sand is within a specified confidence level (Gilbert 1987). The estimated relative standard deviation, $\eta = \sigma/\mu$ is used to calculate the number of required sand samples where

η = relative standard deviation also know as the coefficient of variation

σ = standard deviation ^{226}Ra concentration in the Ft. Funston sand (pCi/g)

μ = mean ^{226}Ra concentration in Ft. Funston sand samples (pCi/g)

The relative standard deviation is a robust and uniform variable from one portion of a survey unit to another (Gilbert, 1987). Gilbert's approach is to specify the relative error, $d_r = |X - \mu| / \mu$ where X is the true mean concentration and μ is the mean ^{226}Ra concentration in the Ft. Funston sand samples.

Probability $[\, |X - \mu| \geq d_r\, \mu \,] = \alpha$ Eq. (1)

$N = (Z_{1-\alpha/2} \times \eta/d_r)^2$ Where Eq. (2)

X = true mean ^{226}Ra concentration in Ft. Funston sand (pCi/g)

Confidence level = $1 - \alpha$

N = number of samples required to satisfy equation 1

$Z_{1-\alpha/2}$ = standard normal deviate that cuts off $(100\alpha/2)$% of the upper tail of a standard normal distribution

GIVEN

The sand samples were analyzed using gamma spectroscopy by EPA Method 901.1. Results are listed in Table 1.

Table 1 Radium-226 Concentrations in Fort Funston Sand Samples (pCi/g)

Fort Funston Sample I	Ra-226
04A-FUNST-001	1.903
04A-FUNST-002	0.5622
04A-FUNST-003	1.334
04A-FUNST-004	1.384

Mean (μ) ^{226}Ra (pCi/g) = 1.605

Standard deviation (σ) of ^{226}Ra (pCi/g) = 1.0650

$\eta = \sigma/\mu$ = 0.6636

04A-FUNST-005	1.14
04A-FUNST-006	3.565

Gilbert's method requires that the ^{226}Ra in the samples be normally distributed. The coefficient of fit (R) of the ^{226}Ra concentrations to the normal distribution using the Ryan-Joiner test is 0.927; exceeding the critical values for six samples of 0.847 for an α = 0.01 (Ryan 1990). Therefore, the ^{226}Ra concentrations are normally distributed.

The range in the true mean ^{226}Ra concentrations (X) in the Fort Funston sand as a function of confidence level for six samples is defined by re-arranging Eq. (1) to Eq. (3)

$X = \mu \pm (d_r \times \mu)$ Eq. (3)

CALCULATIONS

The relative error ranges are calculated for 80, 90, and 95 percent confidence levels for 6 samples.

Given $\alpha = 0.2$, $Z_{1-\alpha/2} = 1.2816$, $d_r = 0.3475$, $N = (Z_{1-\alpha/2} \times \eta/d_r)^2 = (1.2816 \times 0.6636/0.348)^2 =$ 5.99

There is a 80% confidence level (1- α) that $X = \mu \pm (dr \times \mu) = 1.605 \pm (0.3475 \times 1.605) = 1.047$ to 2.163 pCi/g

Given $\alpha = 0.1$, $Z_{1-\alpha/2} = 1.645$, $d_r = 0.446$, $N = (Z_{1-\alpha/2} \times \eta/d_r)^2 = (1.645 \times 0.6636/0.446)^2 = 5.99$

There is an 90% confidence level that $X = \mu \pm (dr \times \mu) = 1.605 \pm (0.446 \times 1.605) = 0.889$ to 2.321 pCi/g

Given $\alpha = 0.05$, $Z_{1-\alpha/2} = 1.960$, dr = 0.531, $N = (Z_{1-\alpha/2} \times \eta/dr)^2 = (1.960 \times 0.6636/0.531)^2 = 6.00$

There is a 95% confidence level that $X = \mu \pm (dr \times \mu) = 1.605 \pm (0.531 \times 1.605) = 0.753$ to 2.457 pCi/g

CONCLUSIONS

Table 2 lists the range of ^{226}Ra concentrations as a function of the confidence level for six Fort Funston sand samples. For example, at the 95 percent confidence level the range of ^{226}Ra concentrations is 0.753 to 2.457 pCi/g. The 95 percent confidence level in the range of ^{228}Ra is 0.857 to 2.799 pCi/g.

Table 2 Range of Radium-226 Concentrations as a Function of Confidence Level for Six Samples (pCi/g)

Confidence Level	α	$Z_{1-\alpha/2}$	η	d_r	Minimum	Maximum
80 percent	0.2	1.286	0.6636	0.348	1.047	2.163
90 percent	0.1	1.645	0.6636	0.446	0.889	2.321
95 percent	0.05	1.96	0.6636	0.531	0.753	2.457
99 percent	0.01	2.75	0.6636	0.745	0.409	2.801

Note: $Z_{1-\alpha/2}$ values are from Table IV of Walpole and Myers (1972)

Table 3 lists the range of ^{228}Ra concentrations as a function of the confidence level for six Fort Funston sand samples. For example, at the 95 percent confidence level the range of ^{228}Ra concentrations is 0.753 to 2.457 pCi/g.

Table 3 Range of Radium-228 Concentrations as a Function of Confidence Level for Six Samples (pCi/g)

Confidence Level	α	$Z_{1-\alpha/2}$	η	d_r	Minimum	Maximum
80 percent	0.2	1.286	0.1278	0.348	1.193	2.463
90 percent	0.1	1.645	0.1278	0.446	1.013	2.643
95 percent	0.05	1.96	0.1278	0.531	0.857	2.799
99 percent	0.01	2.75	0.1278	0.745	0.466	3.190

Note: $Z_{1-\alpha/2}$ values are from Table IV of Walpole and Myers (1972)

REFERENCES

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Attachment 3

Regulatory Definitions of TENORM Requiring Radiological Controls

Regulation of Discrete Sources of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)
The Energy Policy Act of 2005, Public Law 109-058 (NRC 2005) expanded the definition of by-product material established in the Atomic Energy Act as follows:

". . . any discrete source of naturally occurring radioactive material, other than source material, that the Commission . . . determines would pose a threat similar to the threat posed by a discrete source of radium-226 to the public health and safety or the common defense and security."

The Nuclear Regulatory Commission (NRC) defines a discrete source in Title 10 Code of Federal Regulations, Part 30.4 (10 CFR §30.4) as "a radionuclide that has been processed so that its concentration within a material has been purposely increased for use for commercial, medical, or research activities." Discrete sources of radium-226 (^{226}Ra) that the NRC regulates include luminescent dials, gauges, and other instruments used in timepieces, vehicles, and aircraft; industrial radiography sources and industrial smoke detectors; sources used in some industrial products, such as moisture and density gauges; and radium needles used in cancer therapy. Once a discrete source of ^{226}Ra is byproduct material, any contamination resulting from the use of that source is also byproduct material and is subject to regulation by NRC and agreement states. The definition of a discrete source does not imply that it would have physical boundaries separate and distinct from radioactivity present in nature. The NRC deletion of specific physical boundaries from the definition of a discrete source allows the NRC jurisdiction to continue to regulate decommissioning of sites contaminated by ^{226}Ra that was originally present in licensed sources (NRC 2007).

Discrete sources of ^{226}Ra as defined in the Energy Policy Act of 2005 are referred to as 11e.(3) byproduct material and discrete sources of naturally occurring radioactive material, other than source material, are referred to as 11e.(4) byproduct material.

The NRC has not identified any discrete sources of naturally occurring radioactive material (NORM) that meet the 11e.(4) conditions, nor do revised regulations for byproduct material contain criteria that NRC would use to identify such sources (NRC 2007). Thus, there are as yet no NRC regulations for 11e.(4) byproduct material.

NRC has not established regulation for discrete sources of NORM other than ^{226}Ra on the grounds that there are no such sources that are 1) not produced in nuclear reactors and, thus, are already subject to regulations by NRC, 2) pose a threat to public health and safety, or 3) pose a threat to the common defense and security similar to the threat posed by a discrete source of ^{226}Ra.

Regulation of Diffuse Sources of TENORM
Diffuse NORM that has radionuclides concentrated to levels above those found in nature by human actions whether intentional or not is considered to be TENORM (National Research Council 1999). Diffuse NORM that has not had its radionuclide concentrated to levels above those found in nature by human actions but has an exposure pathway altered by humans that increases exposure is also considered to be TENORM. However, Environmental Protection Agency (EPA) has not formally promulgated this definition by rulemaking.

A memorandum of understanding (MOU) between the EPA and NRC on the cleanup standards to be used for decommissioning and decontamination of radiologically contaminated sites includes a table of concentrations of radionuclides in surface soil, referred to as "consultation triggers," that the two agencies agree provide acceptable cleanup criteria (EPA/NRC 2002). Under conditions of unrestricted release, the concentrations of NORM in surface soil includes 5 pCi/g for ^{226}Ra and thorium-232 (^{232}Th) and 47 milligrams per kilogram (mg/kg) of total uranium. The criteria for ^{226}Ra and ^{232}Th are from EPA 40 CFR

Part 192, Subpart B and the criterion for total uranium corresponds to an activity concentration of natural uranium of about 32 pCi/g.

In establishing regulations for newly defined 11e.(3) byproduct materials, NRC was required by a provision of the Energy Policy Act of 2005 to use model regulations, referred to as Suggested State Regulations (SSRs) that were developed by the Conference of Radiation Control Program Directors, Inc. (CRCPD) to the maximum extent practicable. Fourteen states have adopted by rulemaking SSRs developed by the CRCPD for the control of TENORM. The CRCPD SSR Part N section N.4 *Exemptions* subpart N.4(a) states:

"Persons who receive, possess, use, process, transfer, distribute, or dispose of TENORM are exempt from the requirements of Part N with respect to any combination of ^{226}Ra and ^{228}Ra if the materials contain, or are contaminated at, concentrations less than 185 becquerel per kilogram (5 pCi/g) excluding natural background. The progeny of the exempt NORM ^{226}Ra and ^{228}Ra are also exempt." Part N goes on to state under conditions of unrestricted release, the concentrations of NORM in surface soil include 5 picocuries per gram (pCi/g) for ^{226}Ra and ^{232}Th and 32 pCi/g for natural uranium averaged over any area of 100 square meters (m^2). These criteria for unrestricted release are the same as established in the EPA/NRC MOU.

In accordance with Part N, soil would not be regulated as TENORM unless the total ^{226}Ra and radium-228 (^{228}Ra) concentrations in the surface soil exceed their background concentrations by $\geq$ 5 pCi/g when averaged over 100 m^2. Therefore, the sum of the ^{226}Ra and ^{228}Ra concentrations of individual samples could exceed 5 pCi/g above background as long as the average concentration over 100 m^2 does not exceed 5 pCi/g above background.

The ^{226}Ra and ^{228}Ra concentrations in the Building 518 sand samples are listed in Table A.1-1 of Appendix A to Attachment 1. The maximum reported ^{228}Ra concentration (2.32 pCi/g) plus ^{226}Ra concentration (0.963 pCi/g) for a total of 3.28 pCi/g in Building 518 sand was reported in sample 04-PE-0650-12. The average ^{228}Ra plus ^{226}Ra concentrations reported in Table A.1-1 is 2.08 $\pm$ 0.45 pCi/g. The average concentration is less than one-half of the exempt radium concentration limit of 5 pCi/g.

Diffuse sources of ^{226}Ra not regulated by NRC include, for example, scale from pipes used in the oil and natural gas industry, fly ash from coal-fired power plants, phosphate fertilizers, tailings from metal mining and extraction (e.g., tin slag, vanadium tailings, precious metal ores and mine tailings), and residual material from treatment of drinking water to remove contaminants. However, such sources would be regulated by NRC if they contain licensable source material, i.e., at least 0.05 percent by weight of uranium or ^{232}Th, or any combination of the two.

The concentration of uranium isotopes and ^{232}Th in soil equivalent to 0.05 percent by weight is calculated using equation (1).

$$C = M \times IF \times SA \times CF \qquad \text{Eq. (1)}$$

Where,

C	=	Concentration of total uranium or ^{232}Th in soil (pCi/g)
M	=	Mass of total uranium or ^{232}Th per gram of soil (0.0005 g)
IF	=	Isotopic fraction of uranium isotopes in natural uranium (unitless)
SA	=	Specific Activity (TBq/g)
CF	=	Conversion factor, TBq to pCi (2.7027×10^{13} pCi/TBq)

Concentration of ^{232}Th in soil when its mass fraction is 0.05 percent is calculated using Eq. (1):

C = 0.0005g × 1.0 × 4.0461 x 10^{-9} (TBq/g) × 2.7027 × 10^{13} pCi/TBq) = 54.68 pCi/g

The concentration of uranium isotopes in soil equivalent to 0.05 percent by weight was calculated using Eq. (1) and the input and resulting concentrations are listed in Table A.3-1.

Hypothetical soil would require, for example, a concentration of 27.84 pCi/g of ^{232}Th and 170.24 pCi/g of total uranium before the soil would require regulatory control by the NRC as source material. The total uranium, and ^{232}Th concentrations in the Building 518 sand are 2.80 percent of the criterion requiring NRC regulatory control as source material, more than an order of magnitude lower than the concentrations equal to 0.05 percent by mass.

Table A.3-1 Isotopic and Total Uranium Activity at 0.05 Percent Uranium by Mass in Soil

Isotope	Mass Fraction in Natural Uranium[a]	Mass of Uranium Isotope in 0.0005 grams of Natural Uranium (g)	Specific Activity[b] (pCi/g)	Concentration in Soil (pCi/g)
U-234	5.35729E-05	2.67865E-08	6.21030E+09	166.35
U-235	7.20400E-03	3.60200E-06	2.16200E+06	7.79
U-238	9.92742E-01	4.96371E-04	3.35130E+05	166.35
Total U	1.0000	5.00000E-04	6.21280E+09	340.49

Notes:
a. Commission on Isotopic Abundance and Atomic Weights based on Atomic Weights of the Elements: Review by John R L de Laeter, Pure and Applied Chemistry 2003 (75) p. 683 – 800
b. Table 8.4.1 and Equation (2) on page 8-20 of Shleien et. al. (1998)

None of Building 518 sand samples or the Parcel C background reference area sand samples had ^{226}Ra or ^{232}Th concentrations exceeding 5 pCi/g or natural uranium (sum of uranium-238, -234, and -235) concentrations exceeding 32 pCi/g. Therefore, these materials do not represent NORM that is regulated by the NRC.

References

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